ENGINEERING MANPOWER CONCERNS

HEARINGS

BEFORE THE

COMMITTEE ON SCIENCE AND TECHNOLOGY U.S. HOUSE OF REPRESENTATIVES

NINETY-SEVENTH CONGRESS

FIRST SESSION

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ENGINEERING MANPOWER CONCERNS

TUESDAY, OCTOBER 6, 1981

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C.

The committee met at 9:19 a.m., in room 2318, Rayburn House Office Building, Hon. Don Fuqua (chairman of the committee) presiding.

Present: Representatives Fuqua and Harkin.

Also present: Representative Brown.

Mr. FUQUA. The committee will be in order.

Today is the first of 2 days of full committee hearings on engineering manpower concerns. The subject has caused increasing alarm as we have focused on the need for economic recovery and strengthening of our national defense. It is obvious that without the necessary engineering and technical manpower, we cannot hope to proceed in implementing these vital programs. All the advances in science and technology available to us will not prevail if we lack the human resources to apply these advances.

The purpose of these hearings is basically twofold. First, we want to broadly define the extent of the problem now facing us in engineering and technical manpower. Second, we seek to explore the alternative solutions—realistic alternatives, other than simply putting more Federal dollars into more Federal programs. Such solutions might include more cooperative and more direct interactions between industry, government, and the university community than currently exists.

There are a number of questions which should be answered. We need to ask: Is there really a shortage of engineers overall or does it occur only in certain specific areas such as chemical engineering or electronic engineering?

What is the long-term outlook in industry and our universities? Is the educational focus simply at the undergraduate level or at the graduate and precollege levels as well? How do we deal with the problem of retooling a labor force as we introduce new and innovative technologies?

We must also ask: Does there exist a clear national policy regarding engineering manpower? If so, what is that policy and how is it being implemented? What is the proper role of the Federal Government? Of industry? Of the academic community? What steps is this administration taking or planning to take in addressing these and related concerns? What steps should Congress take?

We have a good cross section of witnesses from various sectors, public and private, whom I hope will help us in answering these

and other questions. I look forward to hearing their testimony and exploring these important issues.

On our list of witnesses this morning is Dr. Robert Frosch, no newcomer to this committee, who is now the president of the American Association of Engineering Societies; Mr. Jack Geils, of the American Association for Engineering Education; Gen. Robert Marsh, Commander of the Air Force Systems Command; and Prof. Robert Gaither, president of the American Association of Mechanical Engineers and chairman of the department of mechanical engineering at the University of Florida.

We will follow this panel with Dr. Lewis Branscomb, who is chairman of the National Science Board. We will hear from the witnesses in the order that I called them. So, Dr. Frosch, we would be happy to hear from you first. If you have a statement you would like to insert in the record, we will do that. And, if you want to summarize, your statement in its entirety will be made part of the record.

Before hearing your statement, there is a request to take photographs and recordings during the course of the hearing. Without objection, that will be approved.

[The opening remarks of Messers. Fuqua, Walgren, Winn, and Mrs. Heckler follow:]

OPENING STATEMENT OF HON. DON FUQUA

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We have a good cross section of witnesses from various sectors, public and private, whom I hope will help us in answering these and other questions. I look forward to hearing their testimony and exploring these important issues.

STATEMENT OF HON. DOUG WALGREN

Mr. Chairman, I am pleased to see the full Committee addressing this important issue of engineering and technical manpower. As you have just stated, our nation's economic health and future prosperity depend very directly on the quality as well as quantity of engineers and technicians available to our industries, our universities and our government. We can point with pride to the number of Nobel prizes our scientists have achieved in recent decades, as well as the countless discoveries made

in basic research in the physical and natural sciences. However, it is the engineers and technicians who are able to translate that scientific knowledge into products and marketable services that benefit the economy and society as a whole.

The Subcommittee on Science, Research and Technology as part of its oversight responsibilities held hearings earlier this year in which some of the questions concerning engineers and scientific manpower were addressed. Among the facts we heard presented were:

That enrollement in engineering has increased by over 50 percent in the past decade, while the number of of engineering faculty have declined by better than 10 percent.

That instructional and research instrumentation have become increasingly inadequate and obsolete-students are no longer acquiring "state-of-the-art" training or even near "state-of-the-art" training.

That high industrial salaries are attracting graduate students and faculty out of the universities, thus worsening an already severe shortage of trained educators.

That, whereas our engineering resources both in quality and quantity are declining, Japan, Russia and other international competitors are increasing theirs.

I would make one final point. The steel industry, one of the nation's critical basic industries, has recently announced a new $5 billion initiative in capital investment in new and innovative technology. Obviously some major portion of the 16,000 or more engineers and technicians in the steel industry will require retraining or a refocusing of their job skills. Similar needs can be imagined throughout our nation's industries as new innovations and technologies are introduced. I believe we must focus not only on the training of new engineers but as well on the retraining and retooling of our entire technical workforce as we see the introduction of necessary basic changes in our industries.

I hope we can explore further these and other ideas. I look forward to hearing from our witnesses.

Opening Remarks of Hon. Larry Winn, Jr.

Thank you, Mr. Chairman. I believe that these hearings are an important step in exposing the problems that the U.S. must overcome in order to maintain its competitive edge in the international marketplace. Prime assets of this nation are its scientific and technical human resources. Currently, however, there is a crisis in engineering education of all forms—electrical, computer, chemical and aeronautical engineering. We must reexamine our educational policies, along with the role industry and government play in this vital issue, so that we do not allow American science and technology to atrophy.

U.S. education in mathematics, physical science, and engineering is slipping. Some say that the educational system is an outright failure. Graduate enrollments in engineering, physics, and chemistry have fallen anywhere from 20 percent to 40 percent from a decade ago. Also, because of faculty shortages and increased student demand, many engineering schools are limiting undergraduate enrollments, and this poses a perplexing problem. Colleges and universities have found that they are unable to compete with the salaries industry is offering. This drain of the faculty ranks has taken its toll also at the high school level. The Association of High School Science Teachers decreased by 10 percent over the last year. Most of them were absorbed into better paying positions with firms in the high technology industry. Thus, a current concern regards the quality of engineering education and the longer term implications of a lost generation of faculty.

The rapid rise in industrial salaries has given little incentive for people to remain on the faculty of colleges and universities. For an engineer, a salary with industry is usually at least twice as great as a university salary. Industry's leaders, though, are slowly learning that it is partially up to them to take responsibility for maintaining educated personnel. In a speech last year, David Packard, chairman of Hewlett-Packard Company, stressed that it is in industry's "self-interest" to increase its support to colleges. If long-term consequences are not taken into consideration, our nation's innovative potential could become a vacuum.

Government, working with industry can play a vital role in solving this problem that has taken on an international scope. Last year only 6 percent of the bachelor degrees awarded in the U.S. were for engineering, while Japan had 21 percent and West Germany had 37 percent. The Soviet Union has twice as many scientists and engineers as the U.S., and Japan has six times as many engineers per 10,000 people.

The imbalance in the supply of professionals along with the depleting ranks of engineering professors are problems we must contend with immediately. Society depends on engineering professionals, researchers, and professors to advance the

role of science. During the 1980's a healthy supply of engineers is essential to maintain healthy levels of innovation and productivity.

We must look toward all segments of society, especially industry, to strengthen science education. We must make a long-term investment in science education and science research. The solution of our engineering manpower problems will only come with a dialog between industry, educators, and the government. I congratulate the chairman for initiating today's dialog and look forward to the testimony of this distinguished group of witnesses.

Thank you.

Opening Remarks of Hon. Margaret M. Heckler

Thank you, Mr. Chairman. Ths subject of these hearings is of direct concern to me, because engineering manpower is a critical element of Massachusetts' economy. This topic is also of importance to the nation as a whole since engineers are the backbone of America's efforts to stay competitive in emerging technological industries.

In the last five years we have witnessed enormous growth among high technology companies in Massachusetts as well as the rest of the country. This growth, however, is threatened by competition from abroad and from a scarcity of qualified people. This latter factor, the shortage of engineers and other paraprofessionals, can largely be attributed to our nation's educational system which doesn't seem to adequately motivate or prepare students to enter engineering schools. The lack of emphasis on math and science at every level of education should concern us all.

In a major town outside of Boston along Route 128 where there are a great deal of high technology firms, only one year of math and one year of scinece are required to graduate from high school. In a state already short of qualified science professionals, this fact only compounds the problem. The U.S. ranks a poor fourth in scientific literacy behind the Soviet Union, West Germany, and Japan. In addition, in our graduate schools one out of every three Ph. D. candidates is a foreign national.

In the Boston Globe the recruitment section appears unbelievably thick for a job-short economy. Most of the ads are for the high tech industry. The main reason for this is that the industry is people poor. To illustrate this point, in June 1980 there were approximately 9000 technical and professional positions available in the state. Companies were only able to employ 6000, some 3000 jobs went unfilled. Many New England companies, especially small ones, have been prevented from expanding because of the lack of engineers. Even more significant, it is estimated that for every engineer employed, there are five additional technical, support and administration employees hired, and for each 100 new jobs in the manufacturing sector, an additional 74 jobs are created in other areas such as finance, construction, retail, and so on. This means that the 3000 unfilled positions represent lost employment for approximately 30,000 people.

To maintain its technological edge in world markets, the U.S. must reemphasize science and engineering on our agenda of national priorities. When the Soviets launched Sputnik I, a remarkable engineering accomplishment, the U.S. rose to the challenge with new dedication to science and technology. Today, our technology lead is again being challenged, not just by the Soviet Union, but by Japan, West Germany and others.

Therefore if we are to meet this challenge with the same dedication the space program had, we must shift science and engineering back toward the top of our national priority list.

I am looking forward to hearing from our distinguished witnesses this morning.

Thank you.

[The biographical sketches of Mr. Geils and General Marsh follow:]

BIOGRAPHICAL SKETCH

Mr. John W. Geils is Staff Executive of the American Society for Engineering Education, where he is directing action programs to solve the engineering college faculty shortage problem. He is on loan from AT&T Co., where he was Director, Network Department Administration. In that capacity, he was responsible for budget and expense control for the Network Department and had responsibility for the professional well-being of those in engineering jobs throughout the Bell System, including matters relating to engineering legislation; continuing education; recruitment; placement and utilization of engineers; professional and technical society relations; licensing and miscellaneous personnel matters. Prior to his last assignment he was responsible for the Bell Telephone Laboratories' programs of R&D as funded by AT&T Co., and managed the Technical Suggestions Studies organization.

During his first 23 years he was at Bell Telephone Laboratories, where he performed R&D on telephone transmission systems, military electronics systems and just before being transferred to AT&T Co. spent eight years as Assistant Vice President of the Systems Engineering Department.

Mr. Geils directed the Bell System effort to promote minorities and women in engineering and served in planning the reorganization and consolidation of the National Action Council for Minorities in Engineering (NACME, Inc.) As a member of the Board of Directors of Engineers Joint Council, he served in planning the restructuring of EJC into the new American Association of Engineering Societies (AAES).

Mr. Geils holds a B.E.E. degree from Rensselaer Polytechnic Institute and has attended Columbia University graduate school and Williams College advanced management programs. He was a founding Dean of the Bell System Center for Technical Education, the continuing education facility of the System.

He was born in New York City, is married and has one son.

Biography

United States Air Force

Secretary of the Air Force, Office of Public Affairs, Washington, D.C. 20330

GENERAL ROBERT T. MARSH

General Robert T. Marsh is commander, Air Force Systems Command, Andrews Air Force Base, Md. He directs the research, development, test and acquisition of aerospace systems for Air Force operational and support commands.

Born Jan. 3, 1925, in Logansport, Ind., the general graduated from Logansport High School in 1942 and was attending Wabash College, in Crawfordsville, Ind., when he was inducted into the U.S. Army Air Forces in 1943. In July 1945 General Marsh received a Regular Army appointment to the U.S. Military Academy, West Point, N.Y. He graduated in 1949 with a bachelor of science degree in military arts and sciences, and a commission as a second lieutenant in the U.S. Air Force. He earned master of science degrees from the University of Michigan in instrumentation engineering and aeronautical engineering in 1956. He has also completed Air Command and Staff College and the Air War College, both schools located at Maxwell Air Force Base, Ala.

As an enlisted man in the Army Air Forces for almost two years, he completed both aircraft mechanic and aerial gunnery training on B-17s and B-24s prior to his appointment to the academy. Following his graduation, he attended the Air Tactical School at Tyndall Air Force Base, Fla., and in December 1949 entered preliminary technical training at the Atomic Weapons and Radiological Safety School at Keesler Air Force Base, Miss. In July 1950 he joined the Armed Forces Special Weapons Project as an atomic weapons assembly officer at Sandia Base, N.M. Later, he was assigned to the cadre of the 5th Aviation Field Depot Squadron, an atomic weapon assembly and storage organization, and went with the squadron in 1951 to Sidi Slimane Air Base, Morocco. In December 1952 he transferred to Headquarters 7th Air Division, Strategic Air Command, South Ruislip, England, where he served as an armament and electronics staff officer.

From September 1954 to June 1956, General Marsh attended the University of Michigan under the Air Force Institute of Technology program. In July 1956 he was assigned to Headquarters Air Research and Development Command with duty at Wright-Patterson Air Force Base, Ohio, where he served as project officer in the SM-64A (Navaho) and TM-61-76 (Matador/Mace) weapon systems project offices.

Following Air Command and Staff College in July 1960, General Marsh was assigned to the Ballistic Missile Division, Air Force Systems Command, Los Angeles Air Force Station, Calif. He returned to Maxwell Air Force Base to attend the Air War College from August 1964 to June 1965.

The general was assigned to Headquarters U.S. Air Force, Washington, D.C., in July 1965 in the Office of the Deputy Chief of Staff, Research and Development, as a staff officer in the Directorate of Reconnaissance and Electronic Warfare. He later became chief of the Projects

Division in the Directorate of Space. He completed his tour of duty at the Pentagon as executive officer for the deputy chief of staff for research and development.

In September 1969 General Marsh returned to Wright-Patterson Air Force Base as deputy for reconnaissance, strike and electronics warfare. In June 1973 the general received his first assignment to Air Force Systems Command headquarters as deputy chief of staff for development plans. He became deputy chief of staff for systems in October 1973 and was appointed vice commander in August 1975.

He was commander of the Electronic Systems Division, Hanscom Air Force Base, Mass., from May 1977 to January 1981. He assumed his present command in February 1981.

His military decorations and awards include the Distinguished Service Medal with one oak leaf cluster, Legion of Merit, Air Force Commendation Medal with one oak leaf cluster, Air Force Organizational Excellence Award with two oak leaf clusters and Army Good Conduct Medal. He also wears the master missile badge.

He was promoted to general Feb. 1, 1981, with same date of rank.

General Marsh is married to the former Joan Spears of Crawfordsville, Ind. They have three daughters.

STATEMENTS OF DR. ROBERT FROSCH, PRESIDENT, AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES; JACK GEILS, AMERICAN ASSOCIATION FOR ENGINEERING EDUCATION; GEN. ROBERT T. MARSH, COMMANDER, AIR FORCE SYSTEMS COMMAND, ANDREWS AIR FORCE BASE; PROF. ROBERT GAITHER, DEAN OF ENGINEERING, UNIVERSITY OF FLORIDA

Dr. FROSCH. Thank you, Mr. Chairman. It is a pleasure to appear before this committee again in a new role, for the second time, to discuss engineering manpower problems.

I have a fairly long statement, which I would offer to the committee for the record, and several documents that go with it, which I suspect you might only want to have for committee purposes, and perhaps extract, rather than put in the record in their entirety.

Dr. FROSCH. I would prefer to summarize the main points of my testimony, if I may, at this time.

First, I would like to emphasize, as you, Mr. Chairman, have already mentioned in your introductory remarks, that the role of the engineer has historically been to translate knowledge, design capability, and understanding of what is needed into the design and production of economic systems that are the underpinning of our technological society.

This has been the way in which this country has been productive, has been competitive in the world, and has been economically successful. Without engineers functioning to make this kind of thing happen, we would be in a very difficult position to even run our society, much less improve it and improve its competitiveness.

This is true, not only in industrial and service areas; it is, of course, true in agricultural strength, which has been built upon engineering understanding of how to use land and water and fertilizer and materials.

The principal crisis situation in engineering manpower has been an educational crisis, which I would describe as a crisis as a result of success in the following sense: That the demand for engineers with bachelor degrees has been so great over the past decade, and continues to be so great, that the economic incentives for young engineers with bachelor degrees to go into industrial jobs has

meant that the number of undergraduate engineers going on to graduate school, and the number from graduate school into university teaching, has been decreasing.

The same incentives have applied to many faculty people, so that the numbers of faculty in engineering schools has also been decreasing. We have a number of gaps and shortages.

The result of this problem, accentuated by increasing obsolescence of teaching equipment and modern research equipment, and by other bureaucratic problems, some due to Government regulation and procurement policies for research, have decreased the incentives for the academic life, and the concern is that, with a smaller academic group, we are trying to produce more and more bachelor degree engineers.

It looks as though the educational system in engineering will continue to be overstrained, and the question is: What will the future system for educating engineers be if we continue down the current line? So that, I think, is the central problem of concern, that we cannot see how the educational system for engineers will continue to produce the numbers, and certainly not increased numbers, that appear to be required.

In order to be sure that this is the case, one must have some understanding of whether the current demand and past demand for engineers is likely to continue. Strictly speaking, I think we have no more capability to predict that than our economic predictors seem to have to tell us what the economy is going to do and, in fact, the two have some connection. If there is a major change in a lot of areas of economic expenditure, there will be a change in the demand for engineers.

Nevertheless, the evidence that we get by surveying industry, surveying engineers, surveying industry associations, suggests that the demand will continue strong, at least for the next few years.

If we are serious, as I believe we are, about productivity increase—and this week is National Productivity Week—then it is clear we are going to need engineers to produce the tools that are the ways in which we improve productivity.

History also suggests that over a long period, in spite of many variations in economic activity and economic life, the demand for engineers has continued fairly smooth. There have been periods in which there were fluctuations which caused a great deal of difficulty for some engineers, but if one looks at the statistical situation, those tended to be short term and rather shallow.

So, I think we can expect the demand to continue. That being the case, the crisis problem is real and we need to do something about it.

There is, I think, a general agreement that one of the things, perhaps the central thing that is required to be done is to expand and increase and find new forms of relationships between industry and universities, so that the industries that are the users and employers of engineers will have a close relationship of responsibility to the educational system which is producing engineers.

This comes in a number of forms. One, of course, is direct industrial funding of some things in universities, including fellowships, as the Government has done, and I hope will continue to do; provision of equipment; and in both of those areas, the tax struc-

ture and incentives or disincentives throughout the tax structure for industries to support engineering education and research and development in universities are extremely important.

This brings me to the second important way in which industry can help in this area, which is the direct purchasing—I would call it that—of research and development work from universities. In engineering research and development particularly, there are many areas in which the engineering interests of industry and of university research people should be parallel. It should be possible and, of course, there are many examples which need to be increased, for those incentives to pull together so that industries are, in effect, supporters of research in universities because they want the research results.

Incentives for the industrial provision of equipment will also be important, but I think come best coupled with industry interest in research and development and in interchange of people. That is to say, there should be more use of industry people to assist in education of engineers, and an expansion of cooperative programs for students and use of university faculty as consultants and workers in industrial research and development, particularly.

There are a large number of actions that have begun spontaneously among the engineering societies and with the industry associations and universities, together. I list a number of these at various places in my testimony. I think these are all moving in the right direction. They involve combinations of industry and industry and academic people trying to find ways for industry and academia to work together on this problem.

They are, in most cases, only a beginning, and we need to help and encourage these combinations to expand and to increase their direct effect on strengthening university capabilities. The universities on their side, I think, will need increasingly, as some of them have done but not all, to find new ways to work flexibly with industry in order to make it possible for these combinations and cooperative strengthenings to occur.

The Government has several roles. In one simple sense, the Government is also an industrial partner of academia. That is to say, the Government is a major employer of engineers in a number of its technical agencies, and it must take its share of responsibility for the ability of the universities to produce the engineers that the Government itself will require.

Second, the Government is a major purchaser of engineering product, in the sense of the national defense purchases of high technology, space, energy, and so on. So that it has an important stake, directly, because of the products it wants as a government, in the health of the system that produces the engineers that work in the industries that produce these products.

Finally, the Government has the general policy interest in seeing that the economy is healthy, and as I began, the importance of providing a continuing supply of educated engineers to that economic health must be recognized in the Government's policymaking.

It is in this area of policy that the Government is likely to have its greatest effect. There will be some continuing effect from the direct provision of money for fellowships and for equipment. But by

itself, the Government support of these seems unlikely to be the key solution to the problem.

Those things from the Government throught NSF and the mission agencies, I think, will be most useful if they become catalysts, assisting the industry-university relationships to prosper by adding policy push and in some areas by adding direct money in order to fix up holes and difficulties.

In the area of policy, tax I have already mentioned as extremely important in providing an incentive system. Perhaps, it is most important that we find the disincentives in the tax system and remove those. We need to be sure that the bureaucratic details of Government procurement of university research and development do not in themselves become disincentives, and that the procurement arrangements for industrial research become incentives for cooperation between industry and universities.

Patent policy may be very important in providing incentives for some kind of industrial arrangements with universities. The Government may have a role in that.

There is an area of statutory bar to some of the mission agencies whereby their ability to support education directly is not allowed, while they are allowed to support research and development. I would urge that that question be examined to see whether there may not be an incentive benefit to allowing some of the agencies to consider direct education as part of their support of the research and development package.

Finally, there is probably an influence on all of this by the way in which the Government deals with its policies with regard to information transfer, the policy on export of technology and technological information as it influences the doing of research in industry and in universities, and that, too, should be examined.

Mr. Chairman, I have tried to summarize the shape and scope of the problem as I see it, and to suggest some areas in which legislative action might be appropriate. I am ready at the appropriate time to answer questions and engage in discussions as you desire.

[The prepared statement of Dr. Frosch follows:]

TESTIMONY OF:

Dr. Robert A. Frosch
President
American Association of Engineering Societies

Let me turn now to the current manpower situation. The market demand for new engineers receiving their bachelor's degree has continued to be strong, and competitive forces have kept the entering salaries of engineers at a high enough level to attract U.S. engineering graduates into industry in comparision with the possibility of continued education for advanced degrees. The 1981 edition of the Engineers' Salaries: Special Industry Report by the Engineering Manpower Commission (EMC) of the AAES, which has just been published, note that the median salary for a new engineer with a BS degree and no experience has increased by 11.7% since the 1980 survey. In data obtained from a sample of engineers surveyed as part of "A Pilot Study of the Demand for Engineers," published by the EMC in April of this year, only 0.84% of those responding report themselves as "unemployed, not retired." Leland J. Walker, President of the Accreditation Board for Engineering and Technology, Inc., notes in a letter that: "engineering degrees were 7 percent of the total degrees in 1981, yet they received 63% of the job offers."

In the face of this strong demand for engineers with BS degrees, it has become clear that while industry requires some number of engineers with graduate degrees, the economic bidding for them has been insufficiently strong to result in salary differentials between those with graduate degrees and those with bachelor's degrees sufficiently large to be an incentive for a large number of U.S. engineers to continue in graduate school. The same forces have continued to reduce the attractiveness of academic careers, in comparision with the attractiveness of industrial careers, either for newly graduated engineers or for many faculty members already in universities. Thus we have continued to see few U.S. engineers electing graduate work, and a continuing drain of faculty members from the academic life into industrial jobs.

It must also be said that some of the pressures in this direction are not purely economic, but have been increased by the decreasing attractiveness of academic life forced by the nature of these crisis pressures, and by other bureaucratic changes. The continuing decrease of faculty and of graduate students has led to situations in which large undergraduate loads lead to larger classes, to increased teaching loads, and to fewer opportunities for professional research. This combination has led to a perceived continuing lowering of the quality of academic life, and a decrease in the incentive to enter it or to continue in it.

These problems of academic life have been compounded by the continuing increase of association of government funding of research with a collection of regulatory processes, which, as an experienced government official, I would have to describe as an extension of irrelevant aspects of government life to academic life. These include the introduction of timekeeping accounting procedures into academia that have not been demonstrated to be useful in academic life, or even in many aspects of government life. There has been no demonstration that these accounting procedures produce anything, or assure anybody of any protection against bad practice. In my opinion they merely open

Mr. Chairman, Members of the Committee:

It is a pleasure to appear before you again to testify on various aspects of concerns about engineering manpower. In the seven months since I last testified before you on this subject, there has been a considerable amount of discussion, organization, data taking, and the beginnings of new private action on engineering manpower & particularly on engineering education. This morning, as the first speaker, and as the spokesman for the American Association of Engineering Societies, thus representing the profession of engineering generally, I shall take the privilege of making an overview of the situation, commenting on a variety of issues. I will outline the various subjects of discussions, and describe some aspects of the problem that need further study, as well as some kinds of action which it is important for the various concerned portions of society to undertake. I assume that various other participants in this hearing will describe particular activities that their portions of the system have undertaken.

I will begin by making a few remarks about the role of engineers in economics and national life. It is important to remember that, by themselves, economic manipulations, financial manipulations and management produce nothing. They provide capabilities and opportunities which may be used for innovation and production by others; they are at most a framework within which real action is taken.

The role of the engineer is to provide the translation of knowledge and understanding into the design and the production of products and of the solid technical infrastructure by which the society runs. Without some group of people functioning as engineers there will be little development of new products, particularly of the technologically sophisticated new products which have been the important hallmark of U.S. competitiveness in the world. It must be remembered that even our strength in agricultural production and export has come about through engineered improvements and better technology for the use of water, chemicals, machinery, and the manipulation of land. The same is true of industrial processes, and of the products that we consume and that we depend upon for export in international competitive trade. A shortage of engineering capability would lead to great difficulty in maintaining our productivity, our innovation and our competitiveness in the world.

It is also the case that those things that government does, including the provision of national security and national defense, the space program, the ability to regulate environmental and health concerns intelligently, all depend on the ability of engineers and scientists in government to understand the technical and technological factors that must be dealt with in these subjects. In this sense, the government itself must continue to be an employer and user of engineers and scientists.

an easy door to worse practice on the part of those few individuals who are dedicated to taking advantage of the system. This subject, however, is really rather digressing from my main theme.

Difficulties in academic staffing have been somewhat alleviated in many universities by the use of foreign engineers as faculty members. This practice, however, raises two problems. The first, of course, is whether these engineers are in effect immigrants, and therefore permanent recruits to the U.S. scene, or whether they are merely a temporary force which will go back to their home countries after a while. I do not consider that we have adequate data on this question. The answer clearly bears on the future health of engineering faculties.

The second problem posed by foreign-born engineers in the teaching profession may be described simply as language problems, in some cases compounded by cultural differences from the students they are teaching. I am myself inclined to regard these difficulties as relatively easy to overcome; new foreign faculty members might simply be required to take intensive english language training and possibly some cultural orientation, as part of their early faculty work. Thus this seems to me to be a problem which could be overcome.

The size of undergraduate engineering enrollments has now grown to the point where some schools have had to respond to the shortage of faculty and facilities by limiting the number of students that they will accommodate in engineering. This may limit their problems, but whether this measure leads to a satisfactory national, or even local, situation remains to be seen.

It is a question whether the increase in class sizes for a relatively fixed or even decreasing faculty size, the problems of academic quality of life, and the shortage of modern teaching equipment will leave us in a satisfactory position with regard to the quality of engineering education, even with class size limits. Many state schools may not legally limit their enrollments in this manner. Their educational processes are in danger of breaking down under the pressure.

The comments of Deans of engineering suggest that while the quality of undergraduate students is very high, they have some concern as to whether the strain placed upon faculty and facilities may not be leading to difficulty in maintaining the quality of engineering education. Some Deans feel strongly that the quality of undergraduate engineering education has been forced to decline, and I understand that the number of engineering schools being granted only provisional accreditation is increasing.

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I should also note that the Engineering Manpower Commission of AAES, under an NSF grant, has begun work on the problem of constructing a suitable model of the education of engineers, so that the flow of engineers from academic studies into the profession can be understood, and perhaps predicted, with greater certainty than now possible.

I should now like to make a few remarks about the question of demand for, and utilization of, engineers before turning to the question of the roles of the various sectors of society. We, of course, are not more able to predict the demand for engineers over the next decade or two than we are able to predict the state of the economy, the level of production and business activity that the economy will both support and require, or the effect of weather upon agricultural productivity five years from now. What we really can say is that the demand continues to be very high, and the estimates made by various industries, for example the electronic and computer industry, suggests that in those industries they see a continuing high demand.

In an attempt to obtain additional data, the EMC did a survey of the views of a sample of engineers, and a sample of employers of engineers, concerning the expected demand for engineers a year ahead. I have already quoted unemployment statistics from the published EMC report, "A Pilot Study of the Demand for Engineers 1980". The aggregate of employers surveyed noted that, as of 1 May 1980, they had vacancies for engineers equivalent to 9% of the number of engineers they employed, that they had had a 6% growth in net hires for engineering jobs in the previous year, and expected at 6.1% growth in engineering jobs in the coming year. This expectation was unevenly distributed over specialties, running from a 3.5% growth expectation for chemical and industrial engineers to an 8.1% growth expectation for electrical (which includes electronic and computer) engineers.

The picture is complicated by the fact that employers indicate that the separations of experienced engineers (including retirements) are expected to exceed hires of experienced engineers (but we do not know how much of this is due to normal retirements) by even more than in the 1979/1980 period. This suggests that the hiring demand for new graduates will continue to increase.

Nevertheless, we have seen such predictions change abruptly in the past when there were changes in the economic situation, or in government policy with regard to space or defense, or public works, or other policy matters (such as tax details and regulations) which changed many factors in the economic environment in an abrupt manner. Therefore, while we can make extrapolating models which use the estimates made by the consumers of engineers, their employers and the parts of the economy in which they work, we can by no means be sure of of the stability of these predictions in the face of actual unpredicted, and probably unpredictable, events. We can only be sure, however, that if the society is to continue more or less in the nature of its past performance that there will be a continued strong demand for engineers.

We also know that over a very long period there has been a continued steady and generally increasing demand for engineers. The variations in this demand have tended to be short term, and their statistical effect has generally been small. The decreases have, however, had serious personal effects on a percentage of the engineering population. These personal effects were compounded by difficulties in the movement of the engineers affected from one part of the profession to another, and from one part of the country to another. Professional mobility can be enhanced by opportunities for continuing education; these opportunities can be and are provided within the engineering profession by the structure of professional societies and engineering schools, as well as by special commercial ventures. The geographic mobility problems, however, are not controllable by the engineering profession alone, but depend upon housing markets and mortgage markets and thus are a function of the overall state of the economy. It is my estimate that should there be a sudden geographical shift in demand for engineers, there would be severe problems with their mobility, as with the mobility of any other kind of worker, due to the current difficulties with housing finance and prices.

Another important factor in considering the number of engineers that the economic system will require is the question of the efficiency of their utilization, whether there are engineers doing work related to engineering which could be done by non-engineers, and whether engineers doing work unrelated to engineering could usefully be brought back to engineering if required.

There are two questions involved in this issue of utilization. The first is the question of whether an engineer directly engaged in the work or supervision of engineering is used to the full nature of the engineer's education and skills. This is a function of the infrastructure of support with which the engineer is surrounded. One must inquire whether the engineer has easy access to the data that is needed, whether there is adequate support by technicans, whether there is adequate support by computers, experimental equipment and shops.

This subject is going to be examined by the Engineering Affairs Council of the AAES with a particular emphasis on seeking examples of situations in which engineers are used with high productive efficiency. The characteristics of these situations may be used as examples which other parts of industry may emulate to make impovements in their efficiency of their utilization of engineers.

I touched upon the second aspect of utilization of engineers a moment ago. There are a number of engineers who, in the course of their careers, move out of engineering, either in terms of design and construction work, or even in

terms of the supervision and management of engineering work. They go into other aspects of business, and in fact into other professions. We need to consider whether, should there be a national emergency requiring a great increase in engineering talent, these engineers could be considered as part of the supply of trained people available to meet the emergency. This is a subject on which there is little if any good data. It will be clear from the forgoing that there are a number of aspects of the engineering profession and its role in society that are not completely understood. I have been a member of a committee convened by the National Academy of Engineering (NAE) to examine the possibility of a deeper study of the structure of the profession. I assume that Dr. Courtland Perkins, President of the NAE, will give more details on this committee, and on other related meetings convened by the NAE in the course of his testimony.

Let me now turn to some comments concerning the roles and problems of universities, industry, and government.

To begin with, we need to raise the question whether some of the problems in the university production of engineers might not be eased by changes within academic structure and management.

For example, to paraphrase Gertrude Stein, most universities take the view that "a professor is a professor is a professor." By this I mean that they make the assumption that all faculty members, no matter what their field or subject, or the external demand for the students that they educate, should be paid and treated in the same way. Such an attitude clearly disconnects academic salaries and benefits from the variations of the market place for particular specialties. We already have two common exceptions to this rule in the way in which law and medicine are treated as disciplines within universities; it is common for the faculty in those schools to be compensated and treated by a different set of rules than the rest of the campus. The question must now be raised whether this is necessary for engineering faculty as well. To some degree some change already has occurred in some schools, where chairs and special situations have been arranged for engineering faculty.

It is also generally the case that engineering faculty has freedom to use part of their time and effort in outside consulting work. These opportunities, however, have usually been for the more mature faculty while some of the problem lies with the economics and quality of academic life for the more junior faculty. In addition, increasing pressure of numbers of students has led to heavier on-campus responsibilities, and, therefore, has made it more difficult for many faculty to find the time to do outside work. This increases the difficulty of academic life.

In an attempt to be certain that the problems of engineering schools discussed above were brought to the attention of the overall administrations of U.S. universities, in June, 1981 I wrote to 224 university presidents urging them to consider these problems and work with their deans of engineering to alleviate them. I enclosed a report, "Data Related to the Crisis in Engineering Education," issued in March 1981, prepared for the American Society of Mechanical Engineers (ASME), the American Society for Engineering Education (ASEE), and the American Association of Engineering Societies (AAES) by a special task force.

I would also like to call your attention to a report which I have just received: Engineering Education -- Aims and Goals for the Eighties; An Engineering Foundation Conference, a report of a conference sponsored by the Accreditation Board for Engineering and Technology with the co-sponsorship of athe National Academy of Engineering, the American Society for Engineering Education and the Educational Affairs Council of AAES.

It is also legitmate to ask whether the traditional means of teaching are adequate, or whether new inventions and systems may be useful. While it is possible that some of the traditional lectures and examination systems might be conducted with greater efficiency, and other kinds of personnel brought in to assist the traditional professorial types, engineering education seems to require a high degree of personal contact with experienced and highly educated faculty, and a great deal of hands-on laboratory experience which is difficult to provide on a mass basis. Thus engineering education is likely to be constrained to remain manpower intensive, and the automatic methods used in industry for the production of things are not likely to be of great assistance in improving engineering education, although the use of computer interactive techniques might become an important substitute for some lecturing, and simulation techniques might be an excellant supplement to, and preparation for, intensive laboratory experiences. I believe that not enough has been done in the way of experimenting with these directions, but that they are extenders, not substitutes, for good faculty and good faculty-student contact.

I would now like to make some comments concerning the role of industry. Industry, which uses and depends upon highly trained and educated engineers, must take an important degree of responsibility in seeing that these educational problems are alleviated. I am happy to say that there are a number of indications, and activities underway, that suggest that exactly this is beginning to happen. Mr. Jack Geils will follow me with some comments on these activities, including those undertaken by the American Association of Engineering Societies, the American Society for Engineering Education and a group of interested industrial corporations and foundations. Dr. Robert Gaither has also been involved with several of the major engineering societies and a group of industrial participants. There is also new activity underway by the Association of Land Grant Colleges and a group of industrial corporations; I expect that the American Association of Engineering Societies will be involved in this activity.

Many industrial corporations have recognized that, while a supply of educated engineers has been available as essentially a public good, with only marginal involvment by corporations, the era of such an arrangment seems to be over. Industries must now take a heavier and more direct responsibility for the supply of these educated people, as they do for their supply of raw materials.

The responsibility of industry clearly involves the provision of some money for faculty salaries and for equipment, and the provision of opportunities for faculty and students to contribute to innovation and productivity in industry by part time and supplemental employment. In return for their ideas and work they would be paid, and would receive direct industrial experience which would be of value on the campus. Experienced engineers from industry could also provide a "reality view" from industry as part of the education of new engineers. There have been a number of discussions of the use of part time experienced industrial people (part time meaning either a portion of their time continuously, or a period of time spent on the campus) to supplement the cadre of engineering educators on the campus.

A movement for greater interchange of people and ideas between campuses the industries is building. This can be a great strenghtening of both the educational capabilities of the campuses, by bringing them together with the reality of the practice of engineering in the society in an ever increasing way, and an opportunity for industry to profit from the basic understanding of science and engineering, and the improvements in that understanding which take place on campuses, as well as from the innovative work of campus people directly.

In this connection, at its recent meeting on September 17th, 1981, the Board of Governors of the AAES adopted the following statements as an AAES position:

"1. That the profession, through its practitioners, take a responsible partnership role in engineering education.

2. That concerned employers of engineers cooperate in setting up advisory bodies to Engineering Deans and all engineering departments."

Recent changes in the tax laws, which provide some incentive for industrial giving of equipment and of research and development money, will, we hope, bring about an improvement in the situation on campuses with regard to facilities, equipment and money. In addition a number of extensions of old arrangements, and development of new arrangements for academic research and development work directly in support of industrial interests have been building. We hope that these arrangements can be made in such a way as to preserve the virtues of freedom of research and research interests on the campus, while providing a much better educational and research background for industrial development and production work.

Thus we see a great deal of activity, much of it still discussion, but beginning to move increasingly into new arrangements and relationships for provision of money and equipment, and for interchange of people and research between universities and industry. I can hardly regard this activity as more than the beginning of an important and major increase, but given suitable encouragement and continuation, it will grow into an important and beneficial new set of relationships. We must continue to push these new arrangements and to increase their volume and momentum. The need is very large.

Let me now turn to the role of government.

Government is itself an important industry employing engineers. Engineers and engineering work are essential to the work of the Defense Department, and to other departments of government including Transportation, Commerce, NASA and Energy. These departments use engineers both to do essential in-house research and development, and to provide essential knowledge for their work. As a consequence of this need, the government itself has a stake in the availability of suitably trained engineers: it is a consumer. It is a large consumer. The Statistical Abstract of the U.S., 1980, Table 1079, records that the Federal Government employed 89,200 engineering personnel as of October, 1978. This makes it the employer of about 6% of all U.S. engineers. Thus, as the government faces the universities, it must consider that it too has a responsibility for the health of the machine that produces engineers, quite aside from its more general public governmental responsibilities. The government is in the position of a major employer and user of engineering talent. One of its roles in relation to universities is simply the same as that of an industrial corporation that wishes the supply of educated engineers to continue.

In addition, however, the government is a major purchaser of research and development, and of produced projects of various degrees of technology. In particular, the Defense Department has a direct interest in the health of the industrial and academic systems for doing the research and development which it requires, and for producing the weapons systems which it requires. The government has the responsibility for working with industry to insure the health of the system which produces the products which it needs.

The government has always had a specific responsibility for the health of public education; the basic system of education in the United States. Most of the responsibility for public education has been on the State and local level, but the Federal Government has maintained a responsibility for overseeing its overall health.

In the past, the Federal government has played a central role in engineering education as a principal supplier of the funds that made many of the educational activities possible. While this appears unlikely to continue with the intensity of the past, because of both current economic conditions and philosophies, the government may still play a crucial role with funding used to supply its own needs, and by playing a useful and supportive role through both its direct regulatory (eg anti-trust) and its indirect regulatory (eg taxes) activities. It should also continue to play a direct role in the provision of scholarships, fellowships, and direct support of education in fields directly important to the public good. We do not have a market mechanism for ensuring the supply of public goods, such as national security; especially when they depend on education and research and development which take long times to do.

Finally, the government has a role as an influencer of policy. It exercises this influence through the manner in which it levies taxes, the manner in which it regulates in various areas, the manner in which it controls business systems through anti-trust operations and in general by the way in which it carries out essential pieces of its business, including the national security. It is impossible for the government to have no policy influence, or even a neutral policy influence. Everything it does will influence the way in which business and academia behave.

The government must therefore adopt some attitude as to what it would like to see happen. A supposedly hands-off attitude will in fact not necessarily be hands-off: it is not enough to say "we leave it to the private sector" when the government inevitably takes some actions which influence the way in which the private sector operates. This implies to me that the government must have some explicit policy with which it deals with these problems, if only a policy against which to test such questions as the way in which effects of the details of the tax system, the goverment procurement system for national defense objects, the influence of policy on research and development, etc., affect the production and utilization of engineers and of technology. Attention to public policies that facilitate the kind of private activity that I have described above will be essential.

Areas of concern, although not necessarily for immediate action, include the possible effect of anti-trust attitudes in the Department of Justice on the possibility of industrial consortia and arrangements intended to assist engineering education, the effect of government patent policy on the relationships between industry, government and academia with regard to research and development, the use of research and development for the improvement of engineering education, the effect of procurement and other policies on the health of universities in both research and education, and the policy of government with regard to the publication of information on technology, especially policies related to the export of technology. Policy in these areas should be considered as affecting our ability to improve our technology, and the ability to use it for the improvement of our economy and society; the need for a suitable supply of educated people to do these things, and the need for a healthy educational system to produce these people.

In conclusion, Mr. Chairman, I would like to reiterate that this is an area of great complexity; we are looking for and beginning to find new relationships between industry and academia; the government has an important role to play as a buyer of research and development, a user of engineers and the engineering profession directly in its work. The government is also an influencer, sometimes a controller, of the relationships between industry and academia. The government is an important player, with a stake in the health of academic engineering and engineering education.

The public depends upon the health the engineering profession for the continued operation of economy and industry upon which we all depend.

Mr. Chairman, in the course of this testimony I have referred to several documents. Along with my testimony, I offer the committee copies of these documents for such use as it wishes to make of them.

I look forward to further discussion of these questions in the course of this morning's testimony, and at such other occasions as the committee may choose. Thank you, Mr. Chairman.

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Mr. FUQUA. Thank you very much, Dr. Frosch.

I think we will finish with all the panel members and then go into discussion. I would also like to announce that at 11, we are going to take a short break. We have some committee business pending we need to transact if we have a quorum. Then, we will be back to this.

The Chair yields to Mr. Walgren.

Mr. WALGREN. Thank you, Mr. Chairman.

In our work on the Science Research and Technology Subcommittee, we have been particularly interested in engineering and technical manpower. I do have a statement which I would ask be inserted in the record at some appropriate point at the beginning of the hearing.

Mr. FUQUA. It can follow after my opening statement. Without objection, so ordered. Mr. Geils?

Mr. GEILS. Thank you, Mr. Chairman and members of the committee.

My name is John Warren Geils and I am staff executive of the American Society for Engineering Education, on loan from the A.T. & T. Co., where I was director, network department administration. For 40 years I have been with the Bell System in the continuous practice of engineering development and design and engineering management.

My activities have spanned performing research and development with Bell Laboratories, managing research and development with Bell Laboratories and managing the engineering administration department at A.T. & T., who owns Bell Telephone Laboratories.

I would like to express my appreciation today for the opportunity to testify, as I believe very strongly in the necessity of Government partnership with industry and academe if we are to impact the current deteriorating manpower situation. I will not dwell on the problems. You know the problems. They have been spelled out many times. Dr. Frosch reiterated some of them just a few minutes ago.

But, I want to make two things clear right up front. First, I am not here today to ask you to solve our problem. We in industry and our colleagues in academe have to take on that responsibility. The commitment to that is what has brought me to Washington. My second upfront point is that Government must help us by becoming a full partner to our efforts, and I don't mean necessarily by just providing money. I mean by getting in there, rolling up its sleeves, and working with us to solve some of the problems which have been delineated. On the other hand, industry can't pay for it all.

The basis for much of what has to be done lies in attitude changes, gentlemen. I come from a company that's 105 years old. It has been regulated to the hilt for most of its existence by State and Federal regulatory agencies. I doubt whether any organization in the country knows more about functioning under regulation than the Bell Telephone System.

But, I have seen what in the past several years has been the beginning of deregulation in my industry and I can see what it does to our staff; our manpower and womanpower in the Bell System. I know for a fact that we are going to have to change the

way we look and the way we think about ourselves and our partners in solving this engineering manpower problem.

I know from continuous interface with the colleges and universities, over the years in recruiting and utilization of engineers that they, too, have continuous change to face and they are going to have to swing into a new mode of operations in a very short time. That new mode will be quite different from the collegiate, collegiality mode that they have been used to, in these many years.

I think Government will interface with us and with the academic fraternity and will have to change its image and will have to think in new and different terms also. It is in that area that I would like to address some remarks.

A month ago, I came to Washington to lead a 2-year project funded by eight U.S. corporations. They are all big ones—A.T. & T.; du Pont; Exxon; the three generals, General Electric; General Motors and General Telephone & Electronics; IBM and Union Carbide. These eight corporations asked me to take positive action to solve this engineering college faculty shortage problem.

In addition to the eight corporate sponsors, I am receiving strong moral and organizational support from key colleges and universities across the Nation, and all the professional and technical societies, including both the American Association of Engineering Societies, which represents 39 societies and institutes, and in addition, the National Society of Professional Engineers.

The four tasks that I face are quite clear, and I will mention them briefly. One, I hope to launder the data, clean it up, separate the wheat from the chaff, and work with a body of statistics concerning the shortage and the engineering graduate pipeline situation, that one firm, that we will keep up to date and that can be used reliably by anyone who wants to use them.

Second, I have a very strong coordination function. It has to do with collecting and disseminating information on the many initiatives that have started all around the country. Some of them have started in the professional societies, industries, universities and Government.

My major role is to coordinate and to share the initiatives that have started and are underway. My third major task is to create some new solutions to the problem, new ways for industry and academe and Government working together. We hope, for example, to tap some of the liberal arts colleges, their science and math faculties, who are not exactly fully loaded at the moment, unlike our engineering schools where the load is overwhelming. And, we will implement such a solution like that along with others which we will have to create in the 2 years that I am here in Washington.

The last task is a simple one. It is one of publication to make sure that our findings are known to other organizations and that both our partners in Government and our partners in academe know what is going on from our office here in Washington where I represent, for the most part, industry via these eight major corporations.

Now, the impact of technology on the American economy and on American living is relentless. Every day, our lives are affected in some new way by the increasingly complex applications of technology. It occurs in every walk of life—our communications systems,

our agricultural and water systems, particularly our defense systems and so forth.

The key point, of course, is that these applications are the work of engineers, not scientists. The engineer applies the new knowledge created by scientists in a practical way via designs of new and improved structures, products and services. Thus, as technology multiplies, increasing quantities of quality engineers are vital to the Nation's wellbeing.

We are in a recognized productivity slump and in my opinion, only engineering effort can pull us out. Last October, I chaired a 2-day engineering personnel and productivity conference in Houston, Tex., attended by well over 100 eminent engineers from all over the country. We had a 3-hour session on computer aided design and computer aided manufacturing. Quite naturally, we invited an engineer from the Nippon Electric Co. in Tokyo who addressed the computer-aided manufacturing issues since the Japanese are notably ahead of us in robotics and computer controlled machines.

That company's engineering director came to the conference with the speaker and told me at lunch that when he explains to his engineers about obsolete manufacturing tools and methods, he simply authorizes his people to take a brief trip to the United States and visit almost any plant to see for themselves what obsolescence is all about.

Taking a "systems engineering" approach tells us that there are many inadequacies in every element of the American engineering education system. As in most systems, all elements are co-dependent. By this, I mean every element affects the next.

If we could take a moment to do a hypothetical example, assume a hypothetical faculty person who is overburdened by large class sizes. The first thing that happens is that his or her teaching effectiveness declines and the quality of teaching goes down. Not only does the teaching suffer, but time available for research for our hypothetical faculty person and/or his performing consulting is affected, also.

At this point, our faculty person no longer is a good role model for his students. And, the thing degrades even further. The man or woman in graduate school who is heading for a Ph. D. looks to the faculty and says, My goodness, this guy is really overworked. He doesn't have any time to do the things he would like to do. Why should I continue with a teaching career?

So, he looks elsewhere, perhaps to industry, perhaps to Government, perhaps to private practice, but not to teaching. As a result, our faculty person now has fewer teaching assistants to call upon to help with the load since graduate school enrollments are down significantly. And, our already overworked professor works a little harder and longer and the quality goes down further.

This thing is self-consuming. It reminds one of a malfunctioning Governor on an engine where the engine runs away speedwise and the RPM's increase beyond the red line and the engine eventually destroys itself. And we haven't even mentioned antiquated laboratory equipment and teaching tools.

This situation is recognized by industry and recognized by academe and, I think, recognized by government. But, we are recognizing it late. It came about—the recognition came about somewhat

inadvertently. In the zeal for adding engineering manpower to the work force of our technologically oriented companies, we gobbled up a good many of those people who would make good graduate students.

We in industry created our own graduate programs. Bell Laboratories has a particularly effective one. And, the incentive for the young bachelors level engineer to stay on to teach is hardly stimulating.

I have been in constant contact with major corporate recruiters. We are in agreement that the recruitment, education and utilization elements of the process all need attention. Before this year is out, my company, the Bell System, alone will have recruited over 7,000 college graduates. About 2,000 will be technically trained; that is, engineers and computer scientists. General Electric and Exxon and others have similar numbers to talk about. All of us could use more.

In meeting with GE and Exxon not long ago, we had trouble delineating the role of the engineer as we entered the decade of the 1980's. We know that the role of the engineer and the makeup of our engineering departments must change. We don't know exactly how yet. It is a difficult problem. There are people back at my company and GE and IBM who are working on this concept.

Some of my corporate colleagues have begun massive programs. I would like to point out that on September 17 of this year, Exxon announced a $15 million grant to 66 schools to provide living expenses to graduate students and to provide salary supplements to faculty. Not all corporations can afford to give $15 million. But, others are lining up.

Similar programs have been announced. Some are in preparation. It has been estimated that it will take one quarter of a billion dollars a year to fix and maintain the colleges' laboratory equipment and hardware problems alone, to say nothing about manpower supports.

But, we cannot do this alone. Before giving specific recommendations and wrapping this up, let me say that I believe every sector of our economy, including government, has an obligation to educate the general public on the importance of technology in American life. Living in today's society means being technologically unafraid and adequately informed.

Here is a role that I think government can fulfill and it will not cost a great deal of money, if any money at all. I think the government can join industry and academe in a true partnership. We are going to tell the American people the absolute vital and necessary role of technology in human affairs.

I refer to an organization known as CUTHA, C-U-T-H-A, Council for the Understanding of Technology in Human Affairs, a consortium of over 100 colleges and universities. CUTHA, only 1 year old, is attempting to get liberal arts faculties to understand and teach the importance of technology in today's human environment. Only through real improved understanding can tomorrow's lay civic leaders make intelligent decisions concerning energy, environment, genetics, sophisticated weapons systems, the impact of computers, and so forth.

I refer the Committee to Dr. Edward Friedman, Dean of Engineering at Stevens Institute of Technology in New Jersey, who is chairman of the CUTHA board. I would like to see a government representative on that board of directors because that would lend a great deal of credence to the important point of bringing increased understanding of technology in human affairs to all of our population.

As an individual engineer, and speaking for the industrial sector also, I want to say how much we appreciate what has been done over the years by NSF and other agencies, and we sincerely appreciate the difficulties in sustaining high levels of support year in and year out as political and economic climates change.

Notwithstanding, my recommendations are first, to continue to provide graduate fellowships in the engineering disciplines. Second, to continue a high level of support for R. & D. via NSF and the mission agencies because after all, basic research feeds engineering.

Third, I should like to suggest that we reinstate the NSF program to provide financial aid for undergraduate laboratory equipment. Fourth, I should like to suggest that we make it attractive to the private sector to get involved in direct grants to universities for R. & D., equipment donations and fellowships. By attractive, I mean through some designed tax relief. I'm not an attorney. I'm an engineer. So, I cannot be more specific than that.

Fifth, I would like you to lend your influence and prestige to change the salary structure affecting government-employed engineers. We have all been aware of the brain drain of qualified engineers from government. It is essential to have top flight engineers, particularly in the defense sectors, working with industry, if we are to keep healthy and alive.

Lastly, I would again request that you support, along with industry, this exciting new endeavor known as CUTHA. We should have a government official on the CUTHA board and perhaps modestly help contribute to the new organization's budget, which is being put together right now.

We have asked for your help, but I want you to understand that we in industry and academe are taking our responsibilities very seriously. We know, at least, that industry must be more involved in the educational process than we are now. It is my task in town here for the next 2 years to provide some creative solutions, some ideas how we can work together in a better way.

It may even be that a major restructuring of the educational system will be required. I referred to that earlier when I said attitudes and images must change. This is a point of active debate in my profession, and we don't have all the answers at the moment. But, it is as partners, each contributing to the goal of maintaining quality engineering manpower, in discrete and combined ways, that we will meet our needs and our collective obligation to the quality of life in this country.

Thank you again, Mr. Chairman, and members of this committee.

[The prepared statement of Mr. Geils follows.]

Statement of

John W. Geils

Staff Executive
American Society for Engineering Education

The following testimony is in support of the request that funds be appropriated and government effort be dedicated to assist a fast-evolving team effort between industry and academe to improve the quantity and quality of engineering education in the United States.

My name is John Warren Geils, and I am Staff Executive of the American Society for Engineering Education, on loan from AT&T Co., where I was Director, Network Department Administration. For 40 years I have been with the Bell System in the continuous practice of engineering development and design and engineering management.

I would like to express my appreciation for the opportunity to testify today, as I believe very strongly in the necessity of government partnership with industry and academe if we are to impact the current deteriorating engineering manpower situation.

A month ago I came to Washington to lead a two-year project funded by eight major U.S. corporations (AT&T Co., du Pont, Exxon, General Electric, General Motors, General Telephone & Electronics, IBM and Union Carbide) to take positive action to solve the engineering college faculty shortage problem. In addition to the eight corporate sponsors, I am receiving strong moral and organizational support from key colleges and universities and all of the professional and technical societies including both the American Association of Engineering Societies which represents 39 societies and institutes and the National Society of Professional Engineers.

The impact of technology on the American economy and on American living is relentless: every day our lives are affected in some new way by the increasingly complex applications of innovative technology to our industrial and domestic tools, transportation systems, agricultural and water systems, defense systems, communication systems, energy systems, etc. The key point, of course, is that these applications are the work of engineers -- not scientists. The engineer applies the new knowledge created by scientists in a practical way via designs of new and improved structures, products and services. Thus, as technology multiplies, increasing quantities of quality engineers are vital to the nation's well-being. We are in a recog nized productivity slump and only engineering effort can pull us out. Last October I chaired a two-day engineering personnel and productivity conference in Houston, TX., attended by well over 100 eminent engineers from all parts of our country. We had a three-hour session on computer-aided design and manufacturing, and quite naturally invited an engineer from Nippon Electric Co. in Tokyo to address the computer-aided manufacturing issues since the Japanese are way ahead of us in robotics and computer controlled machining. The company's Engineering Director came to the conference also and told me at lunch that when he explains to his engineers about obsolete manufacturing tools and methods he simply authorizes his people to take a brief trip to the U.S. and visit almost any plant to see for themselves what obsolescence is all about!

A systems engineering approach tells us that there are inadequacies in every element of the American engineering education system, and, as in most systems, all elements are co-dependent. By this I mean every element affects the next; e.g., if a faculty person is overburdened by large class sizes, his or her effectiveness and efficiency degrades and the quality of teaching goes down. Not only does teaching suffer, but time available for research and/or consulting is affected. At this point our faculty person no longer is a good role model for students to continue in graduate school to Ph.D. level which is the key to filling future faculty posts, and a turned-off B.S. candidate looks elsewhere for a career -- to industry or government or private practice, but not to teaching. Our faculty person now has fewer teaching assistants to help with the load since graduate school enrollments are down significantly and the already overworked professor works a little harder and longer, and quality suffers another decline. Meanwhile, the demand from industry steadily increases, normal competition sets in, and starting salary rates go up -- a current average figure is $25,000 for a B.S., more than many associate and assistant professors earn. University administrations panic and limit undergraduate enrollments. The supply worsens. The system is on the verge of self-destruction in much the same way as a malfunctioning engine governor lets the RPM's increase well beyond the "red line", and the engine destroys itself. And, we haven't even mentioned antiquated laboratory equipment and teaching tools!

I have been in constant contact with major corporate recruiters and we are in agreement that the recruitment, education and utilization elements of the process all need attention. Before this year is out, my company alone will have recruited over 7,000 college graduates. About 2,000 will be technically trained (engineers and computer scientists). We could use more. Some of my corporate colleagues have begun massive programs of aid. On September 17th of this year, Exxon announced a $15 million grant to 66 schools to provide living expenses to graduate students and salary supplements to faculty. Other companies have announced similar programs or have them in preparation. It has been estimated that it will take one quarter billion dollars a year to fix and maintain the colleges' laboratory equipment and hardware problems.

But, we can't do it alone! Before giving specific recommendations, let me say that I believe every sector of our economy, including government, has an obligation to educate the general public on the importance of technology in American life. Living in today's society means being technologically unafraid and adequately informed. Government must join industry and academe in a true partnership if we are to apply a systems engineering approach to solving the engineering education problem.

As an individual engineer and speaking for the industrial sector also, I want to say how much we appreciate what has been done over the years by NSF and other programs, and we sincerely appreciate the difficulties in sustaining high levels of support year in and year out as political and economic climates change.

My recommendations are:

1. Provide graduate fellowships.

2. Continue a high level of support for R&D via NSF and the mission agencies. Basic research feeds engineering.

3. Reinstate the NSF program to provide financial aid for undergraduate laboratory equipment.

4. Make it attractive to the private sector to get involved in direct grants to universities for R&D, equipment donations and fellowships.

5. Lend your influence and prestige to change the salary structure affecting government-employed engineers. We have all been aware of the brain drain of qualified engineers from government. It is essential to have top-flight engineers, particularly in Defense, working with industry.

6. Support along with industry an exciting new endeavor known as CUTHA -- Council for the Understanding of Technology in Human Affairs. (A consortium of over 100 colleges and universities is attempting to get liberal arts faculties to understand and teach the importance of technology in today's human environment. Only through real improved understanding can tomorrow's lay civic leaders make intelligent decisions concerning energy, environment, genetics, impact of computers, sophisticated weapons systems, etc. Dr. Edward Friedman, Dean of Engineering at Stevens Institute of Technology in Hoboken, N.J. is Chairman of the CUTHA Board.) Specifically, financial aid is required and a government official should be placed on the Board of Directors.

We have asked for your help, but I want you to understand that we in industry and academe are taking our responsibility very seriously. We know at least that industry must be more involved in the educational process than we are now. It may even be that major restructuring of the educational system will be required: this is a point of active debate in our profession at this time. But it is as partners, each contributing to the goal of maintaining quality engineering manpower supply in discrete and combined ways, that we will meet our needs and our collective obligation to the quality of life in this country.

Thank you again, Mr. Chairman, and members of the Committee.

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Mr. FUQUA. Thank you very much, Mr. Geils. We appreciate the fine work that your group is performing.

Our next witness is General Robert Marsh, Commander of the Air Force Systems Command at Andrews Air Force Base.

General MARSH. I welcome the opportunity to appear before you today to express my views on what I see as a critical problem, the shortage of trained engineering and scientific manpower. As I explained in my formal statement, which I would like to insert for the record——

Mr. FUQUA. Without objection, we will make the entire statement a part of the record.

General MARSH. I believe the technological power balance is shifting away from the United States. I believe to a large measure, this shift is due to the lack of scientific and engineering manpower. If I'm correct in this causal relationship, then we face a long-range problem as the shortage is not susceptible to quick solutions and the situation is likely to be with us for some time.

The world is becoming more and more dependent on advanced technology, a fact that has escaped few people. Not widely appreciated, however, is that the United States now lacks and probably will lack for some time the necessary scientists and engineers to satisfy the needs of industry, government, and academia to allow for future technical growth of the Nation.

The Bureau of Labor Statistics estimates that the United States will be short 16,000 engineers each year through 1990, the cutoff of the study. A quick analysis of our capability to produce those engineers is disappointing, although a look at the statistics does show some growth in output. The United States yearly production of baccalaureate degrees is now about 58,000 up from 38,000 in 1975. The number of masters degrees increased about 7½ percent from 1979 to 1980. The number of Ph. D.'s decreased slightly to 2,750 over the same period.

However, these figures are offset by the fact that a significant portion of the growth is due to foreign students. Foreign enrollment has doubled since 1975 and is currently at 47 percent of Ph. D.'s, 40 percent of masters degrees and 8 percent of bachelors degrees.

Although some estimates show production increasing to 65,000 in 1983, I am not sure that it is realistic to expect significant growth beyond current levels unless concerted action is taken. I question the estimates of significant growth because I am not certain there will be a significant supply of engineering students entering the universities or that the universities can handle the load.

The student supply is limited by demographics and secondary school curricula. U.S. secondary school students receive inadequate emphasis on math and science courses: only 9.1 percent take physics; only 16.1 percent take chemistry; only 3.4 percent take calculus and seven States require no high school math at all and, we have seen a 15-year decline in scholastic aptitude test scores in both math and verbal skills.

Compounding these concerns are estimates in demographic studies which show declines in the 18-year-old population in the mid-1980's, which will lower the number of students entering engineer-

ing schools unless motivation and preparation to enter engineering is increased.

I question whether the universities can handle significantly increased loads because engineering schools are both understaffed and inadequately facilitized. Maintenance of an experienced technical faculty is difficult because instructors are being lured away by higher industrial salaries.

Engineering school facilities reflect old technology and are badly in need of expensive modernization, estimated to require an investment of somewhere between $200 million to $250 million a year. Current facilities average about 30 years of age.

While we are suffering from insufficient engineer production, our strongest adversary, the Soviet Union, shows just the opposite trend. The U.S.S.R. currently graduates about 300,000 engineers a year, five times our production rate. They show a 300 percent increase since 1960 compared with our modest 50 percent.

The U.S.S.R. currently has 1½ times as many scientists and engineers on the job as the United States. With the high rate of engineer production, the U.S.S.R.'s technical manpower pool may soon dwarf ours. The potential for technological breakthrough is, indeed, worrisome to me. One need only examine what the Soviet emphasis on their technical base has accomplished during the past decade—MIRVS, new missiles, radars, and so forth—and this worry comes into tight focus.

And, other countries are very committed to increasing their technical manpower pool as well. Japan, with half our population, produces more engineers than we. Their agressive push into high-technology world markets graphically demonstrates the effect of their emphasis on technical manpower.

In 1978–79, Japan graduated 65,400 engineers as compared with the United States's 54,600.

Now, let me give you some specifics on the effects the engineer shortage is having on the military. As Commander of Air Force Systems Command, I am a heavy user of technical manpower and I assure you I am feeling the strain of the current shortage.

I have about 52,000 people in my command; about 12,000 are scientists and engineers. The workload is heavy. We have over 40,000 contracts totalling over $100 billion. Our work is highly technical and covers the entire spectrum of technical activities—research, development, test, and production of sophisticated weapon systems. As you can see, we are absolutely dependent upon having a sufficient pool of technical personnel.

But, for some time, I have not had a sufficient pool, and I see the situation worsening. I am about 10 percent short of engineers, which, as I understand it, is about the same position as my industry associates. My programs do suffer from that shortage. My programs also suffer from the fact that almost 40 percent of my military engineers are new and unexperienced lieutenants. I have had to adapt to the shortage in ways I don't like. Many technical programs are now managed by junior people, some with nontechnical training.

The shortage causes me to rely more on decisions made by contractors, and I do not feel comfortable that our contractor workload

can be effectively monitored and controlled by the technical management manpower that I have.

The end result, as you might imagine, is that some programs are being managed inefficiently, costing the taxpayer dollars, and providing the Air Force reduced capability and readiness. Promising technical areas are not being capitalized on as well as they should be and I suspect technological opportunities are being totally overlooked because our people are too busy or too inexperienced to see they are there.

We have a large number of personnel programs to improve both recruitment and retention of our engineering force—just as industry has done—and we have made some progress over the past few years. The military pay increase currently being finalized by the Congress will help greatly.

However, all of our initiatives and more pay cannot solve the problem. We are playing a zero-sum game. There simply aren't enough engineers to go around; and from the statistics I have seen, there won't be enough for some time unless concerted, national action is taken.

The engineer shortage problem is real. It must be solved if we are to remain competitive in the international arena and if we are to retain a sound defense. The problem is a complex one that involves industry, academia, and government. It can only be solved by a national resolve to do so—and do so we must if we are to preserve our position as the leader of the free world.

Now, I will not pretend to know all right solutions, but let me list a few general ideas which I feel should receive attention. Establish a clear national goal to retain U.S. leadership in science and technology. I see a parallel between today's situation and that caused by the launch of Sputnik in 1957. After that shocking event, the entire country was motivated to catch up, culminating in the national commitment to put an American on the Moon. I hope such a shock is not required again. But, nothing short of the national commitment we made for the Apollo Moon program will do here if we are to maintain leadership.

Restructure primary and secondary school curriculums to strengthen early technical education to prepare students and motivate them toward engineering careers. Increase compensation for technical educators to allow academia to compete with industry. Institute a long-range plan to increase the capacity of our universities by the 25 percent or so necessary to meet future needs. Modernize and improve educational facilities to both improve the current facility situation as well as expand to meet additional needs. Defense and industry should participate in this effort.

Promote increased technical education for women and minorities. Foster increased public appreciation for the challenges, benefits and wonders of science.

For the military, we must maintain pay comparability with the civilian sector; increase ROTC scholarships, and provide additional education to provide the advanced degrees needed to maintain our technology edge.

My recommendations could be embodied in one word—commitment—a national commitment clearly backed by our leaders.

That, Mr. Chairman, concludes my remarks. I will be happy to answer questions at the appropriate time. Thank you.

[The prepared statement of General Marsh follows:]

STATEMENT OF

GENERAL ROBERT T. MARSH

COMMANDER

AIR FORCE SYSTEMS COMMAND

Mr. Chairman and members of the Committee, I welcome the opportunity to appear before you today to express my views on what I see as a critical national problem--the shortage of trained scientists and engineers. I will also discuss the consequences of this shortage and offer thoughts on what we must do to correct the problem.

As Commander of Air Force Systems Command (AFSC), I rely daily on highly qualified scientists and engineers to make tough technical decisions dealing with the acquisition of the most complex, sophisticated capable systems in the world. Unfortunately, I do not have all the technically qualified and experienced people I need. This shortage hampers the ability of my command to fulfill its mission, and worse, endangers the economic health and defense capability of the country.

I know I share the Committee members' view that the United States must maintain leadership in the technological arena. Unfortunately, there is real evidence that all is not well. Consider the following examples:

-- U.S. patents issued to foreign nations grew from 17 percent in 1960 to 38 percent in 1979.

-- Foreign controlled portion of the U.S. consumer electronics market increased from 5.6 percent in 1960 to 50.6 percent in 1979.

-- Foreign controlled portion of the U.S. metal working machine tool market grew from 3.2 percent in 1960 to 28 percent in 1979.

There are many more examples; the list is a long one and includes most of the technology areas that are key to leadership in the international arena.

Our international competitors, both friend and foe, have been aggressively building their technological base, as well as outproducing us on both the production line and in the universities. This trend of foreign gain coupled with U.S. declining emphasis on technology, productivity and technical education is causing a rapid shift in the technological balance. I can only conclude the U.S. is approaching the loss of its world technological leadership, a loss that could have severe economic and security consequences.

I contend that a key element of this shifting technological balance is the growing shortage of trained scientific and engineering personnel. Let me examine some of the factors which led me to that conclusion and then discuss the military scientist and engineer shortage as it relates to Air Force Systems Command, what we have done to work the problem and what must be done to solve the engineer shortage problem nationally.

The rapid growth and expansion of technology plays a major role in everyone's life today. The military and the defense industry are among the leading "consumers" of technology and have the largest demand for scientific and engineering personnel. The trend of increasing requirements for scientists and engineers to

work in research, development and application of technology shows no sign of abatement.

Unfortunately, the American colleges and universities are not producing the required number or level of technical graduates to meet the increasing demand of the military, industry, and the universities themselves. Specifically, a Bureau of Labor Statistics manpower study for the period 1980-1990 projects a net nationwide shortfall of 16,000 engineers each year.

Now let us consider the "supply" side of the supply-demand equation and, in particular, consider current and projected trends in engineer production as well as the potential inherent in engineering colleges and universities to respond to the need for increased engineer production.

Let us consider recent trends. The number of bachelor degrees awarded to engineering students increased steadily from about 38,000 in 1975 to about 58,500 in 1980, and will continue to 65,000 in 1985. After remaining fairly constant for several years, the number of master's degrees in engineering rose to about 17,250 in 1980 (an increase of 7.5 percent over 1979), whereas the number of PhDs dropped only slightly to 2,751 from 2,815 during the same period. Overall, the trends appear to be healthy, but there are indications they cannot continue and that they are in fact misleading.

First, the great increase since 1975 could mislead one to believe we are on the ramp of real, sustained growth. But, in reality, 1975 was the low point in engineer production in the past 15 years. That was the year when the dramatic drop in enrollments from 1970-71 showed up. You may remember the depression of the aerospace industry that received national attention in 1970. Thousands of engineers were out of work, and I remember vividly the billboard erected in Seattle that read, "Will the last person leaving Seattle please turn out the lights?" This did not go unnoticed by our youth, and caused engineering careers to look uninviting.

Second, when the engineer production figures mentioned earlier are modified to eliminate foreign student statistics, we find we have realized only a small gain in total output for U.S. engineers in recent years. Foreign student enrollments in U.S. engineering programs doubled between 1975 and 1979. In 1980, foreign students comprised 47 percent of the total enrollment in engineering at the doctorate degree level, 40 percent at the masters and eight percent at the bachelor level. We are, in fact, spending a significant part of our engineering training effort on people who are potential competitors and this adds further to the shifting technological balance I mentioned earlier.

Third, one should also examine the realism of the peak projection for 1985. Based on demographic trends, the number of engineering

bachelor degrees awarded each year will peak at about 65,000 in 1985 and decline fairly steadily to about 46,000 in 1995. If my understanding is correct, engineering departments are straining to capacity right now, therefore, I question whether or not we can even reach that peak in 1985.

I am somewhat discouraged upon examining the potential for the U.S. educational system to respond to projected requirements for engineer production. The system lacks both the necessary "raw material" and "plant" capability. Too many students leaving high school are largely unqualified and unmotivated to pursue engineering; and, the facilities needed to improve engineering production are both understaffed and inadequately equipped.

The lack of "raw material" is the end result of a "grass root" problem starting at our secondary school level where students are ill-prepared and not motivated to prepare themselves for technical careers. Consider the following:

-- There has been a 15-year decline in SAT scores both in mathematical and verbal, and in science and mathematics achievement test scores.

-- Just 3.4 percent of secondary school graduates have had one year of calculus; in the Soviet Union, all students get two years of calculus.

-- Only a small percentage of secondary school graduates have taken courses in science subjects: physics--9.1 percent; chemistry--16.1 percent; and biology--45 percent.

-- For most students, their last mathematics course is 10th grade geometry; their last science course is 10th grade biology.

-- Only about one-sixth of all secondary school students currently take junior and senior year courses in science and mathematics.

-- Seven states require no high school mathematics.

The result is that emerging high school graduates are ill-equipped to pursue engineering, or other technical courses of study at the college level.

And, even if students were motivated, or required to take such courses, a problem exists in having sufficient trained faculty to teach the courses. This stems from the fact that the faculties of technical high schools and colleges are lured to industry by high salaries. This vicious cycle undermines the capability of the supplier to produce technical graduates, much less improve production. Said another way, we are feeding our seed corn to the cattle so they won't starve this year. However, next year when there is no seed to grow corn to feed to the cattle....

Educational institutions are not only hampered by lack of adequate faculty, but also by the lack of adequate facilities. While some of the more renowned universities have been able to build new facilities, on the average engineering college facilities are about 30 years old.

Acceleration of technological progress during the last two decades has exacerbated the problem of outdated laboratory equipment. A growing gap exists between instructional equipment and equipment utilized in industry. A study sponsored by the

National Science Foundation states "The median age of the university instrumentation was twice that of the instrumentation in two major companies," and "University researchers frequently observe even the best industrial laboratories in this country do not compare with foreign laboratories."

Several years ago, the Engineers Council for Professional Development estimated that the new equipment needed by an engineering college would cost $100,000 per year per program, plus $150 per student per year. Most engineering colleges have nothing close to this amount at their disposal.

Given all these considerations, I seriously doubt that the dynamics of supply and demand can solve the problem. Thus, I foresee a serious, even critical, gap between the requirements for engineers (and other technically competent people) and potential supply unless we as a nation do something about it. I will suggest specific fixes later.

I mentioned that other countries emphasize the importance of engineering education. Well, our major competitors, both friend and adversary, appear to be committed to increasing their technical resources. Specifically, the Soviets graduate some 300,000 engineers annually--over five times our current rate. This represents a 300 percent increase in USSR engineering student output from 1960. In the meantime, the U.S. had a modest

50 percent increase--with a significant amount of the increase attributable to the foreign students I mentioned earlier.

Currently, the Soviets have over 900,000 full-time scientists and engineers engaged in research and development, compared to 600,000 in the U.S. A large percentage of those Soviet scientists and engineers are believed to be engaged in defense related R&D -- the comparable U.S. number is about 150,000. The payoff to the Soviets can be seen in the unbelievable gains they have made in sophisticated defense systems during the last decade--in aircraft, in missiles, in space systems, in electronic systems--all of which refute the notion, held by some, that the Soviet engineer is inferior to the U.S. engineer.

Japan, with only half the population of the U.S., graduates more engineers each year than we do. We can see examples of the Japanese push towards utilizing high technology for economic advantage on any U.S. highway or in any electronics store.

Given the shortages I have reviewed, it is easy to see that academia, defense and industry all have problems. But problems for defense and academia are magnified by competition. That is, industry can and does outbid us and academia for technically qualified people. For example, in 1968 the Air Force recruited over five percent of the college engineering graduates. Currently, we are able to recruit about one and a half percent, far short of our goals.

Industry draws from the same trained engineering pool as the military but with about $7000 higher starting salaries. In addition, this salary difference is widening as competition among companies for scarce resources increases and industry bids up the price. Industry also couples salaries with excellent peripheral support plans such as additional schooling, family medical/dental plans, complete insurance plans, house purchase plans for transferred employees, excellent move reimbursement programs, and so on. Industry also sponsors scholarship initiatives which attract future engineers right out of high school.

In my view, industry has clearly recognized the national shortfall in scientific and technically educated people, increasing requirements, and the need to provide both immediate and long-term solutions. This recognition has led to corporate redefinitions of the three "Rs" - recruit, retrain and retain. Perhaps they should have added another "R"--refurbishment of academic facilities.

Industry, like the Air Force, recognizes that recruiting alone cannot supply the needs of the 1980s, and is, therefore, placing increased emphasis on retraining--continually educating to meet changing demands--and retaining--finding new, more effective ways to keep their scientific and technical people.

Let me shift my discussion of the engineering shortage as a national problem to show with specifics how it affects Air Force

Systems Command (AFSC). To give you an idea of my perspective, AFSC employs 70 percent of the Air Force scentific and engineering officers and currently spends 31 percent of the annual Air Force budget. If measured on a "business volume" basis, AFSC would rank 12th in the Fortune 500's listing of largest corporations.

As the major research and development arm of the Air Force, Air Force Systems Command is charged with advancing aerospace science and technology while developing and acquiring the best aeronautical, space and support systems at the lowest possible cost. In accomplishing these efforts, we administer over 40,000 contracts which have a face value of over $100 billion.

Out of a total Systems Command population of 52,000 military and civilians, approximately 12,000 are technically qualified in the scientific or engineering areas. About 40 percent of this number are military officers--scientists and engineers--who are engaged in every aspect of the aeronautical and space technology acquisition process from concept to deployment.

Simply stated, there is no facet of the Air Force acquisition process which does not depend on the technical competence of scientific and engineering people. At one end of the spectrum, we conduct pure research in the laboratories to provide new ideas or state-of-the-art improvements in the mathematical, physical, engineering, environmental and life sciences. At the other end,

test centers rigorously "check out" and evaluate a weapon system as it is being brought to operational readiness. However, most of my people are employed between these two poles in System Program Offices (SPOs) which are charged with acquiring aircraft, missiles, electronic systems and conventional weapons.

On one hand, the business of AFSC is very much like that of our industrial counterparts. All of the elements are there, particularly the shortage of scientific and engineering personnel. On the other hand, we are unlike them in a critical area--we lack their flexibility to expend whatever resources are required to recruit and retain all the quality personnel we need. This inability is so serious that we--as a command, as an Air Force--may become severely limited in our ability to maintain technological superiority in weapons if we do not confront this problem head on---and solve it.

The proposed increases contained in President Reagan's defense budget will create an immediate demand for even more technically qualified people in programs such as the Long Range Combat Aircraft. Thus, I see my problem about to get even worse. But this is not new, the engineer shortage has been a fact of life for Air Force Systems Command for more than five years.

Since 1976, we have seen our engineering resource base steadily erode to the point that now the Air Force as a whole is nearly 1,100 Military Engineering Officers short of our minimum needs.

And Systems Command, as the primary user of this critical Air Force resource, is short over 500 military engineers--or 10 percent. This shortage is particularly acute in the electrical, astronautical, and aeronautical engineering disciplines which form the nucleus of our engineering force.

Further, the shortages also translate into an experience drain. During the last three years, Systems Command suffered a net loss of nearly 7,500 man-years in military engineering experience. Unlike industry, we cannot hire into middle and top management levels. We must "grow our own"--and to date we simply have not been able to replace this experience.

We face potential experience shortages on the civilian side as well, since about 20 percent of my civilian engineers will be eligible for retirement in the next five years. Our civilian totals, however, are not as bleak--thanks to a concentrated recruiting effort during the beginning of this year which increased our civilian technical manning level from 93 percent to 98 percent. This does not sound too bad at first blush, but 157 of my civilian engineering positions are still vacant, and with the high retirement rate ahead, the future is uncertain.

Like industry, we have recruited aggressively to fill our military engineer ranks, and in the past two years we have seen some payoff. We now have on board 1,750 new lieutenants in all of our engineering disciplines. In fact, lieutenants now

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comprise one-third of AFSC's total engineer force; worse yet, by 1985 they will comprise one-half. These new officers, as welcome as they are, have not reduced our shortage--only stopped it from getting worse.

Although they are bright and eager, lieutenants fresh out of college are inexperienced and obviously do not compensate one-for-one for the experience we have lost in recent years. The combination of lost experience and new officers has created real problems in our already technically shorthanded organizations.

These problems directly affect the efficient defense of the country. Let me explain. AFSC and Air Force Logistics Command (AFLC), the Air Force command responsible for logistical support of all weapons systems in our operating commands, must rely increasingly on contractors to perform work we used to do in-house and even have had to reduce Air Force monitoring of those contractors. We also have had to delay or defer work. This is having a direct adverse impact on both the modernization and readiness of our forces. For example:

-- The Air Force Wright Aeronautical Laboratories at Wright Patterson Air Force Base now contract out 86 percent of all new projects. This is an increase of 12 percent in just three years.

-- In one program, the Intelligence Data Handling System, the labs have a validated requirement for 46 technical people--we can only assign 26.

The reduced Air Force monitoring of our ongoing activities leads inevitably to problems going undetected longer and more costly

fixes and bigger schedule slips when problems are detected. Some examples:

-- One of our satellite programs recently suffered a technical problem which we believe could have been detected and corrected sooner and less expensively if only an experienced engineer had been available--estimated cost is seven million dollars.

-- An inexperienced officer allowed a conflict between associate contractors to linger longer than prudent. Impact--the delivery schedule slipped and the cost increased two million dollars.

I believe these problems are just the "tip of the iceberg." My system program office directors are reluctant to tell me they cannot do the job, but the fact is that people are increasingly becoming the limiting resource. This has led to delays or deferred work in promising technology areas. For example:

-- In our labs, we started the Aviation Turbine Fuel Technology Advanced Development Program which we hope will develop advanced fuels to reduce our dependence on high cost foreign petroleum. We have had to slow the program down because of lack of people. Ultimately, this slow down will cost us in additional petroleum costs and cause us to continue to rely on foreign supply.

-- We have started technology programs in the space countermeasures arena which require 15 additional technical people--we have only been able to assign one.

-- AFLC has not been able to develop new, non-destructive inspection procedures for detection of fatigue damage in B-52 and A-7D aircraft. This has adversely affected the operational readiness of these aircraft.

-- AFLC attempted to contract out 264 Minuteman Missile circuit boards--no bids were received. The work had to be scheduled in-house, but, because of engineer shortages, the work will take three years versus the originally scheduled two years.

-- In another instance, AFLC lacked the engineering manpower to promptly identify the need to correct

damage left after pylon hole rework. Wings on three aircraft had to be reskinned--at a cost of $600,000.

I can continue to cite the growing list of examples, however, my fear is that we will not see the full impact of the current shortage for several years when we quite possibly find weapons systems failing to perform to expectations. In the future we may very well find design failures, cost overruns, and missed opportunities that potentially could cost the nation dearly. In other words, even though the primary mission is currently being accomplished, required work is not being performed and it is already costing us both dollars and operational readiness, and the situation is likely to worsen.

The problems I have been discussing are not new to the DOD community, nor are they easily solved. Let me assure you we are not just sitting on our hands waiting for a magic solution. We have been exploring new ways to build up our manpower pool, and, more importantly, keeping the good people in whom we have invested so much time, training and money. We have been pushing hard, and with the support of Congress, we have made improvements in compensation for all DOD personnel. These improvements have brought our pay and benefits closer to comparability with the civilian sector, although in the scientific and engineering fields there is still much to be done.

Additional improvements are being considered right now including the proposed 1 October pay raise, initiatives to reduce the

financial impact of moving, and a new version of the G-I Bill Education Program -- one benefit for military people that has proven to be a major positive force in attracting people to the military services.

Let me shift gears now and address some of the specific programs we have come up with to help solve our engineering shortages in the Air Force.

We have assigned some of our best engineers and scientists to recruiting service to help search for talent. We are sending young scientists and engineers on extended visits to universities to try to sell the Air Force as a career--when they can elbow their way through the industrial recruiting teams. They tell it like it is, the good and the not so good. They also tell why they made the decision to stay with the Air Force as a career.

The more than 30 separate initiatives being implemented to attract, retain, and improve the productivity of engineers in the Air Force include the following:

-- Increases in ROTC scholarships from 6500 in FY 81 to 7000 in FY 82 with proposed increases of 500 per year through FY 85 (pending Congressional approval)

-- Increases in the Airman Education Commissioning Program from 309 in 1980 to 450 in 1983. Through this program, airmen with some college education in science and math are sent to college full-time to earn an engineering/ scientific degree.

-- The College Senior Engineering Program. This exciting program offers college engineering students the opportunity to enlist in the Air Force at the beginning of

their senior year. The students receive full senior airman pay and allowances/benefits while they go to school. Upon graduation, we send them through Officer Training School, commission them, and place in an engineering job. Our FY 82 recruiting quota is 150 versus 85 for FY 81.

-- The co-op student program which is designed to attract students into our civilian engineering work force. We have approximately 500 people in the program and enjoy an 80 percent retention rate.

-- Increase in the Air Force Institute of Technology programs, both at the undergraduate and graduate level. This year, 160 newly commissioned officers and 60 from active duty with technical degrees were sent to AFIT for a BS in electrical or aeronautical engineering --an increase of 100 over last year. On the graduate side, approximately 570 highly qualified officers were sent back to universities to receive advanced engineering and scientific degrees--a 12 percent increase.

There are many other worthwhile initiatives, but these examples indicate to you how we are trying to work the problem ourselves. Unfortunately, these are "nickel and dime" initiatives. They do not--and will not--solve the problem alone. In fact, we in the Air Force cannot work the problem very well because it is national in scope and solutions are vested with institutions not under our control. But let me provide some suggestions:

If this nation is to retain its position as first and foremost in world technological leadership, the nation must pursue a comprehensive, decisive and far-reaching national educational policy for the coming decade which includes the following:

(1) We must set a national goal to be first in the world in the scientific and technological fields.

(2) We must completely restructure the primary and secondary school curricula to provide an education strong in the scientific and technical areas. This includes upgrading the facilities as well.

(3) We must support increased pay and benefits to attract the quantity and quality of teachers needed to ensure a quality education for our students.

(4) We must implement a long range plan to increase the capacity of our institutions to turn out quality scientists and engineers in the numbers needed to handle the challenges of the future. Defense and industry can and should participate in this undertaking by supporting major facility upgrade projects which directly increase capability.

(5) We must promote the scientific and engineering education of a vast untapped resource--the minorities and women of this nation.

(6) We must develop and implement a comprehensive program to increase the public's awareness of the challenges, benefits and wonders of science. For example, the cost of the Voyager mission to Jupiter and Saturn of one cent per person was compensated many fold not only by our increased knowledge but by the young imaginations which were set to wonder at the sight of Io, Europa, Rhea, and Titan, the storms of Jupiter and the rings of Saturn.

(7) We must place significantly increased funds into research and development for challenging and far-reaching projects to ensure that advances will be there when we need them.

(8) For the military--we must ensure that we have the ability to attract and retain the quantity and quality of scientists and engineers we need to provide a strong military force. Specifically, this involves increased pay to achieve and maintain parity with industry, increased ROTC scholarships, additional education and family benefits to enhance retention, and increased graduate education quotas to provide the advanced degrees to ensure excellence in academic and military skills.

My recommendations for resolution of this critical problem are embodied in one word--commitment--a total and continuing national effort to build a scientific and technical capability which is second to none. We need to promote and encourage a cooperative, rather than competitive environment among the various sectors which employ engineers with more efficient and productive use of this scarce resource.

How unfortunate it is that I should be here talking to you today about maintaining parity with an adversary when, with the total talent available within this nation, we should be talking about technological achievements and advancement. We are at a crossroad in the history of our nation. Difficult decisions must be made, not only in the area of technology, but with many personnel problems facing us today--decisions which will establish our course of action into the next decade. The future of this nation, and our way of life as we know it, is at stake.

Mr. FUQUA. Thank you very much, Dr. Marsh. We appreciate your remarks. We will now hear from Prof. Robert Gaither. We are happy to have you with us.

Mr. GAITHER. Thank you, Mr. Chairman. I, too, am grateful for this opportunity to appear before you and provide some testimony on the problems surrounding the engineering education and manpower.

First, I would like to offer my compliments and support for the fine testimony that has been given by my colleagues already this morning. I hope that I can be viewed by all of you as being a person of two resources. First, I am an educator in mechanical engineering, a very basic discipline, a discipline which is required by every industry in the United States.

I have never, in all of the period of time as an educator, had any of my students not find a job. Through the worst of the recession period, instead of 7 to 10 job offers, they only received 2 or 3. But, they always got a job; they have always been needed and will continue to be needed.

So, what we see today in the way of a shortage, I believe is nothing more than the worsening of a problem that existed 10 years ago. I have been an educator and mechanical engineer for over 30 years, 17 of which have been as head of the Department of Mechanical Engineering at the University of Florida. I am in that part of the academic world where I believe the problem is the most critical.

In my second role, I am the president of the American Society of Mechanical Engineers, a volunteer organization which has an enormous array of resources. It has 105,000 technical members, 32 technical divisions, 7,000 people working on a council of codes and standards, establishing standards of safety for industry throughout the world. In fact, we have a literal army of people that are dedicated to making sure that this country remains at the top of the heap in the technological manpower world.

So, I have an unusual perspective with these two roles. I can assure you that there is a problem. I can further assure you that it has been with us for a while. It is very bad now and it is going to be with us for a considerably longer period of time. You just simply can't take an English professor and/or a person out of industry and throw them into a thermodynamics classroom and expect him to be able to perform immediately.

I could provide you with additional statistics. I have already written to almost, I believe, all of you on this committee and many of the other Members of the Senate and the House of Representatives and provided you with data on this problem. I could provide more.

I have here a list of the responses from many of you and many of the other members of government indicating that they are aware of this problem. But, I think it would be better if I told you how it was affecting me personally.

For the last 5 years, the productivity of the Department of Mechanical Engineering at the University of Florida has increased by 300 percent. I have three times as many students to handle as I did 5 years ago with the same faculty. I have 6 open positions in a faculty of 26. That's a 20 percent, not a 10-percent shortage.

I haven't mentioned the fact that I am lacking in space. I have two offices to put those six new faculty members into. I have a shortage of equipment; that which I do have is overaged. I don't even have the funds to pay for the maintenance on the equipment that I have. Unfortunately, the situation in my department is somewhat typical.

I don't presume that there are going to be any quick solutions to this situation. I don't believe that any partnership is going to solve this immediately. In fact, it has got to be a limited partnership. Education has got the heart of this problem. They are going to have to solve it. But, we are going to need some help.

In the way of advice, I would suggest that you avoid some nonsolutions. There has been much attention given to the number of non-U.S. citizens teaching engineering in the United States. Today, just under one-half of our graduate students in engineering are not U.S. citizens. As you seek to find solutions, you should avoid those quick fixes such as a legislative cutoff of foreign engineers into our system. This is not a solution. We need some of them.

Also, I think in this time of budgetary restraint, it is not realistic nor even desirable to think of government funds bailing out the educational situation. I do believe that government can obtain commitments from industry, volunteer organizations such as the American Society of Mechanical Engineers, universities, and the general public to provide support, even if no other way, but simply recognizing that we really do have a problem here.

I would like to see encouragement of agencies of the Federal Government assist in providing the engineering schools with assistance in their real problems of manpower. It would seem to me—again, I'm not a lawyer—that the tax incentive kind of thing that could be provided by the Government might be something along the lines of offering to industry the possibility of paying some portion of their taxes to me instead of to you.

I hope that the Government will obtain a commitment from industry. I can assure you that the volunteer organizations are already trying their hardest to get into this problem and get a handle on it. There will be many groups wrestling with this problem in the next few months. In January of next year, the American Society of Mechanical Engineers, along with other founder societies, will be having a forum. There are other forums that are going to go on in the spring. We are going to support those forums.

We are going to invite members of the other technical societies and people that are presenting some of the testimony here before you today. Hopefully, we will have members of government as well. We are going to attack this problem and come up with some solutions.

Finally, I would like to say that ASME with its volunteers and resources stands ready to do what we can to help in this dilemma which is facing our Nation today. I am in a position right now to offer the resources of this society to your committee.

Thank you.

[The prepared statement of Mr. Gaither follows.]

STATEMENT OF

ROBERT B. GAITHER

President
The American Society of Mechanical Engineers

Engineering Manpower and Education

Before the
Committee on Science and Technology
U.S. House of Representatives

6 October 1981

My name is Robert B. Gaither. Thank you for this opportunity to appear before you and provide testimony on the problems surrounding engineering education and manpower. First, let me offer compliments and support to the fine presentations that have already been made before you this morning by my colleagues. I hope that I can be regarded as two resources. The first role is that of an educator in the field of mechanical engineering where the manpower problem is especially critical. Mechanical engineering is not a specialty but a basic discipline. It includes, but is not limited to, such specialties as automotive engineering, power engineering and energy engineering. Indeed, mechanical engineering is recognized as the broadest of engineering disciplines. William Everett (an eminent scholar and Dean of the University of Illinois) perhaps described it

best when he said "If it moves, a mechanical engineer designed it". Mechanical engineers design all kinds of things that move including aircraft engines and dynamos, spaceships and submarines, printing presses and heart valves. I have been a mechanical engineer for over 30 years, seventeen of which have been as a Professor and Head of the Department of Mechanical Engineering at University of Florida. My second role is that of the President of a large volunteer technical society, the American Society of Mechanical Engineers. With one hundred and five thousand members, this volunteer society has an enormous array of resources including thirty-two separate technical divisions, a volunteer council comprised of over seven thousand members actively engaged in the establishment of codes and standards to support public safety and an education council which aids in accreditation and development of Mechanical Engineering curriculum. Indeed, ASME is comprised of a literal army of dedicated and technically expert men and women who wish to play a part in the development and implementation of solutions to the manpower problems that face our country today.

These two roles I have give me quite a perspective on the engineering manpower problems in our country. As I have indicated in previous testimony before this committee the American Society of Mechanical Engineers has gathered, published and distributed a wealth of supporting statistics surrounding this issue. We have worked closely with our sister

technical societies in doing so. We have had the opportunity to tell you the problems of finding qualified faculty for the Universities and have presented you with a article written some time ago called "Engineering Education: Are We Eating Our Seed Corn". General Marsh also referred to this vicious cycle in his testimony to you.

I could convey to you personal remarks made to me by industrial recruiters, shipyard executives, leaders of the armed forces and captains of industry telling me that we have a short supply of engineers. But rather, let me convey to you the situation as it confronts me personally. My faculty is overloaded. We have a record enrollment. Six out of the twenty six faculty positions in mechanical engineering at the University of Florida are vacant. That is approximately 20% of my faculty. I am encountering extreme difficulties in locating competent people willing to dedicate their lives to teaching mechanical engineering. A year ago I lost one of my best professors to industry. They simply doubled his salary. Added to this, I have an extreme shortage in space, office and laboratory equipment. I don't have sufficient funds to maintain the new equipment that has recently been donated to us.

The situation at my school is sadly typical. What are the solutions to these problems? I don't presume to have the solutions to a situation that has been a long time coming. But, I believe I can offer a few observations. First, I can tell you what I think are not solutions to this dilemma we find ourselves in. There has been much attention given to the number of non U.S. citizens teaching engineering in the U.S. Just under half of our graduate students in engineering are not U.S. citizens. As you seek to find solutions, we should avoid quick fixes - such as legislating a cutoff of foreign engineers and engineering professors. This is not a solution. We need some of them. Also, I think in this time of budgetary restraint it is not realistic, or even desirable, to think of the U.S. Government coming to the rescue. Government does, however have an abiding interest, from a National Security Standpoint, in the supply of technical manpower.

Government can obtain commitments from industry, volunteer organizations, universities and the general public to provide support by simply recognizing that the viability of our technology based society depends on supporting quality engineering programs.

We would like to see encouragement of agencies of the federal government to cooperate with industry to assist the universities in providing the engineering and technological manpower that this country so desperately needs today. Perhaps it is idealistic, but I can envision a joint effort between the universities, industry and government to solve these problems so vital to every sector of our society. It seems to me quite logical that a privately funded non profit organization can be

developed that could orchestrate professor exchanges, the loan of government and industry personnel for part time or temporary teaching assignments, equipment loans from industry, facility sharing between local industries and universities, etc. I hope that the government could obtain a commitment from industry and volunteer organizations to provide time, funds and manpower to help get our engineering schools at high productivity again. Such a joint effort could produce a well spring of ideas on to approaches this very serious problem.

There are many groups wrestling with the problem and in the next few months there will be many conferences held to discuss this pressing problem. In January of next year, the American Society of Mechanical Engineers, along with other engineering societies will be conducting an action forum and inviting participants from government, industry, the military, and other engineering societies, including those who have representatives before you here today. It is our hope that from this forum and the others being held by other organizations will come viable solutions to this manpower problem confronting us. We are pleased to have been given this opportunity to demonstrate our willingness to play a part in the solution. Industry, universities and government must collectively embark on programs to restore the attractiveness of careers in engineering education. Industrial and government demands for engineering graduates can be expected to remain high, as my colleagues have pointed out. If the demand for engineers doesn't stay high, there is no way that our national economy can be expected to meet foreign competition. ASME with its volunteers and resources, stands ready to do what we can to help solve this dilemma facing our nation today.

Mr. FUQUA. Thank you very much.

I wish there was some way that we had to divert taxes to various places. I'm afraid we are going to have one centralized collection and then have to fight among ourselves as to how they are doled out. It is a very innovative idea, though.

I am very intrigued by what industry is doing in wrestling with a problem that affects you and also, it affects most of the university community. General Marsh, I noticed in your statement, and I am familiar with some of the programs, that ROTC is emphasized and that you are planning to increase the number of ROTC participants.

That's just for the bachelors degree, is it not?

General MARSH. That is correct, Mr. Chairman. It is for just the bachelors degree. We are in-house trying to increase our AFIT, Air Force Institute of Technology, program for advanced degrees. We have been growing that at a steady rate for years.

Mr. FUQUA. Do you think some modification of the GI bill would also encourage young people to go on for a graduate degree?

General MARSH. Sir, I do. After they get out of the service, I definitely think that would enhance the availability of technically trained personnel. Obviously, it would help us with our retention problem. We are very much in favor of the GI bill for both reasons.

Mr. FUQUA. Professor Gaither, of course professors' salaries were indicated as a problem. Still, as I gathered, the real problem is not for bachelors degrees because you have indicated you have increased 300 percent, I believe, over the last number of years. It was pointed out in General Marsh's statement that there is a decline in the number going into the masters and doctor of philosophy programs.

That's where the problem seems to be, that we are not resupplying or recharging the stream that we need for the researchers, the professors, and those that will be carrying on the teaching needed. This is the requirement that we have which I think has been very well outlined from the perspective of industry, the military, and professional organizations.

Mr. GAITHER. That's exactly right.

Mr. FUQUA. That seems to be a problem.

We are going to have to recess the hearing momentarily. Mr. Brown will take over.

Mr. BROWN. The problem we are discussing this morning is one that has been before the committee as long as the committee has been here, I guess. It is one we have tried to deal with constructively. For example, we have charged the National Science Foundation with responsibility for doing something about many of these problems. Specifically, we have encouraged the Foundation to look more diligently at the problems of engineering and technical manpower, and engineering education.

The program that you suggested, Mr. Geils, the CUTHA program, is one which, it seems to me, is a natural in terms of the mandated functions to encourage engineering education. Can you give me any indication whether support has been sought and whether it has been received, favorably or unfavorably, or if there have been some mundane things such as lack of resources which may have prevented them from doing the job?

Mr. GEILS. The CUTHA organizing people have been in touch with the National Science Foundation. I believe they have added to their board Dr. Lloyd Cook who is a member of the National Science Board at NSF. I believe that contact has been established and is evolving.

When you are only 1 year old, as CUTHA is, you have a lot of work to do in order to get your chestnuts lined up before you can actually function. It is still in an organizational stage.

Mr. BROWN. You cannot indicate at this point whether there has actually been an effort to get some supporting funds through that source in order to promote CUTHA program?

Mr. GEILS. I don't know for sure. But, I don't think they have approached NSF for funding. I know they have approached industry. We have processed their request at A.T. & T.

Mr. BROWN. General Marsh, I really was struck by your testimony. I think it was very much to the point. It put its finger on some of the key problems that we have. I admire the breadth of your perspective on this. I would hope that there would be voices in the executive offices listening to what you have said.

It reiterates many of the things that we have said here, particularly the need to establish a national goal of achieving this scientific and technical excellence. Now, you have an excellent channel, the new science adviser, who is extremely sympathetic to the needs of the military, who has indicated he proposes to devote a good deal of his time to that, and who in turn is charged under the National Science and Technology Policy Act with a responsibility for scientific and engineering manpower.

Have you had any discussions with him or do you think that it is possible that you might be able to enlist the support of the President's science adviser in trying to establish these national goals and sense of commitment?

General MARSH. Sir, I have not had any personal contact with him as yet. I think it is entirely possible to do so. I believe we will be taking steps to try and bring this problem personally to his attention and solicit his participation in this.

Mr. BROWN. Dr. Frosch?

Dr. FROSCH. Mr. Chairman, I might comment that a group of us from the American Association of Engineering Societies as well as representatives of a number of the engineering societies individually, have had discussions with Dr. Keyworth about this problem. He is aware of the difficulties and some of the proposed solutions, and has expressed considerable interest in participating in the formulation of Administration policy to help in this area.

Mr. BROWN. Dr. Gaither?

Mr. GAITHER. I feel a necessity to clear up a point here, because I see the words engineer and science being bandied back and forth as equivalents. I admit there is a great deal of overlap between the two. There are people in both areas that do work in the other area.

But, I would point out that there are not today a shortage of physicists. There is not today a shortage of chemists. Nor is there a shortage of mathematicians. The word engineer comes from the Latin ingeniator, which means clever contriver. These are people that put things together and make machines. The word engineer is

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spelled with an "i" after the Latin in all of the European languages, but it is not so in this country.

An engine is a device that was contrived by a clever contriver. But today in this country, we tend to use the word engineer to mean engine operator. There is a big difference between these. Certainly, when you are talking at the level teaching in universities. We are talking about people that are very highly sophisticated in their knowledge on what the engines of tomorrow are going to look like rather than operating the ones of today.

The use of these words scientist and engineer I think has to be very carefully done. I would commend you to be careful with that.

Mr. BROWN. Well, as you know, Dr. Gaither, I have been concerned about that for a number of years. But, the fact is that we charged the National Science Foundation with the responsibility for engineering and technical policy problems as well as scientific research problems. I am proceeding on that basis rather than my own sometimes expressed view that possibly an alternative mode of handling the problems of engineers would be desirable.

But, I concur in the point that you are making. Dr. Frosch, you have had extensive experience at NASA and other places with the problems of engineering manpower in the Government and, of course, outside of Government as well.

But, are you aware of any general policy or commitment on the part of the Government that would complement what General Marsh said about a commitment to the achievement of outstanding or preeminent excellence in this field? In other words, do we have a national manpower policy for engineering personnel with a mechanism for examining and looking at the sort of things that you described that will enable us to act effectively?

Dr. FROSCH. Mr. Chairman, I am not aware of a comprehensive policy with regard to technological manpower or engineering manpower. There are a number of agencies of Government that are charged with collecting statistical data on all kinds of manpower, including engineering manpower and scientific manpower.

There are some individual areas where there have been goals enunciated. But, I don't know of a comprehensive U.S. goal of technological excellence, certainly not in the past few years.

Mr. BROWN. Are you aware of any directives or policy guidance from OMB dealing with this general problem?

Dr. FROSCH. I do not recall over the past several years any that directly dealt with that problem. There are some policy distinctions in Federal manpower regulations with regard to professions and occupations in which the country is short of people. And those apply in Government hiring of engineers, scientists, and others.

But, I don't think that would correspond in my mind to a specific policy with regard to that. I may be being forgetful, but nothing certainly stands out as significant.

Mr. BROWN. General Marsh, do you have any comments from the standpoint of the military on this? You have expressed the need for a national policy and commitment. How close have we come to having one that you are aware of?

General MARSH. Mr. Chairman, I likewise am unaware of a real, stated national policy or commitment that addresses the problem in the broadest sense. However, I must say that there have been a

number of individual initiatives taken by the Department of Defense and, in turn, supported by the administration and the Congress, that attacked the problem in many ways.

As you, I am sure, are aware, for the military, we recently proposed successfully a bonus for engineers that would aid in the retention of engineers in the military service. And, I believe just yesterday, or recently, in conference, that bonus was approved. We obviously have succeeded well in the administration and with the support of Congress in raising the ROTC scholarship program from some level around 5,000 up to near 10,000. And so, I think our individual initiatives that we have constructed to address this problem have had strong support, Mr. Chairman.

Mr. BROWN. But, it seems to me that the things that you are describing are sort of antidotes to our failure to have a policy rather than a policy. We do this for specialties in the medical field or veterinarians or whenever we find that we have failed to provide for the ongoing supply or the conditions which will give us retention of needed specialties in the military. Then, we do these special things in order to remedy that situation.

But, I don't think that's what you had in mind in terms of a national commitment to excellence in engineering and technical fields. Perhaps I'm mistaken.

General MARSH. No, Mr. Chairman. I believe you are not. I did have in mind a broader commitment, a national commitment.

Dr. FROSCH. Mr. Chairman, if I may, I think that it is clear that we have been unwilling nationally even to state that we felt that technology was extremely important to us as a national interest, much less that technologists, therefore, were of special importance. So, in some areas, I think we are reaping some difficulties as a result of that.

Mr. GEILS. I would like to lend industry's support to General Marsh and Bob Frosch on the issue of having a national policy statement. We are running a national meeting in April of next year; industry and academe are together. The Business Higher Education Forum is involved. And, we are preparing right now a "declaration of intent", much like the Delaration of Independence.

We hope to have high-level people in Government and industry and academe sign that declaration of intent. There will be some action plans forthcoming as part of it. But, it is leading to the national policy statement which General Marsh so rightfully asked for.

Mr. BROWN. Well, I'm sure you are aware that we have made efforts in the past on this committee and in the Congress and in the executive branch to move in this direction. But today, the emphasis is going to be on greater responsibility by private industry and academia.

I think this is a real challenge and one which industry particularly should rise to in the sense of providing the sense of urgency and encouragement for the enunciation of this kind of policy. I think the policy, even without the sin of throwing large amounts of Federal dollars at the problem, may be helpful in itself.

It may set a framework within which we can establish this cooperative relationship which, again, is not something that you are suggesting. This is something I think all of us are committed to

do who have studied the problems that we are describing. Yet, we have got to be able to make a great deal of progress at our level.

Dr. FROSCH. Mr. Chairman, it would seem to me that an enunciation of policy might be most important with regard to the attitudes of secondary school and primary school teaching, education, and students in the sense that Jack Geils mentioned earlier, the importance of seeing that that early education, which is the underpinnings of understanding technology, is important, not only for those who go on to become engineers, but also for those who don't go on to become engineers, but who take other roles in the society: important for them so that they can understand what it is that is going on in the technological society.

There is an attitude problem and the establishment of a kind of official national attitude, in a sense, might help in generating greater interest and understanding of what is at stake in this area.

Mr. BROWN. I'm sure it was. But, I'm equally sure that the organization that you and Mr. Geils represent can be a powerful influence in encouraging local education to make this change in emphasis that you so badly need.

Dr. FROSCH. We will be trying to do that.

Mr. BROWN. I'm going to recognize some of our other members. Mr. Dunn?

Mr. DUNN. Realizing that you gentlemen are the experts——

Mr. BROWN. May I interrupt just a moment?

Mr. DUNN. Of course.

Mr. BROWN. I would like to invite Cooper Evans to come up and sit with us. I know of his great interest and background in this area. Just because he isn't a member of this committee, we shouldn't be deprived of his expertise.

Mr. DUNN. Realizing that you gentlemen are the experts and we are supposed to ask the questions, I would nevertheless like to throw out a couple of different possible solutions that do not involve Government support.

I represent Michigan State University, one of the largest engineering schools in the country. I spent some time at U of M this summer and I also spent some time at General Motors, one of the largest firms in the country hiring engineers. I would like to talk about the problem of retaining people at the graduate level.

The arguments, and you correctly stated them, seem to be that industrial salaries outweigh the advantages of staying in school. GM, in talking to me, said yes, we definitely need doctor of philosophy level people. And yet, I have some doubt—and, McDonnell Douglas said the same thing to me—whether that is really the case. In looking over their pay schedules, there is very little difference between what they offer a doctor of philosophy versus a typical graduate engineer. If they really need this and there really is a demand function of the market, there should be a bigger difference.

If in creating this industry difference, you give students adequate encouragement to stay, that would be solution number one. If industry has this demand, recognize it and make the pay different.

Number two, and more significant in my opinion, relates to the problems of funding for fellowships and also to the problems of foreign students, particularly in engineering.

General Marsh pointed out statistics, 47 percent, 30 percent, and 8 percent. The nationwide average seems to be around 20 percent. Most of our universities are State schools, and they are State subsidized. I did some figures with Michigan State University. Per foreign student, it costs the taxpayers of Michigan almost $2,000 per year per student. That was based on the true cost, fixed costs, and variable costs.

If it costs $2,000 per foreign student and if the majority of those foreign students are taking our technological expertise back to their own countries and becoming our competitors, why should we subsidize them? I would raise the point that we should not be, that we should raise their tuition that $2,000 and to give you some figures on what happens when we do that. Michigan State right now has approximately 4,000 students in engineering. Take my minimal figure of 20 percent times 4,000, and you get 800 students.

If you charge those 800 students an extra $2,000, you come up with $1,600,000. I would propose that we use that $1,600,000 to increase the level that we pay fellowships to encourage American students to stay at the graduate level program.

It is not a cost to the Government or to the university. The only possible fallout from that would be if, because of the $2,000 increase, foreign students would no longer attend our universities. To a man, I got an answer of negative. We do have the best educational system in the world. When they are calculating the cost of coming here from France, Germany, or India, the $2,000 doesn't even cover their airplane flight over here.

So, we will not stop them from coming. My question is what's wrong with that? Why wouldn't it work?

Mr. GAITHER. If I can respond to some of it, there are basically two questions there. If industry has the demand, why don't they support the graduate students in the schools?

Mr. DUNN. No. Why don't they pay? It is a very minimal difference.

Mr. GAITHER. You are correct with General Motors. Let me give you some information on that. I lost a faculty member about a year ago to Exxon. All they did was double his salary. That's all. They said, whatever you are making right now, we will pay you double to come and work with us. They did it and he's there now.

Unfortunately, his name is Roger Gater, and with a name like that, I could really use him at the University of Florida. [Laughter.]

Two years ago we had a yearlong visit from a man who will probably be the head of his corporation. They paid his full industrial salary, paid for all of his wife's and children's travel expenses to get to the University of Florida. He sat and worked with us. He wrote six papers. Each one of those six was a milestone.

That man was from the Hatachi Co. They sent us $6,000 just to make sure he was happy while he was there. He wasn't from General Motors.

With regard to the cost of foreign students, our big problem is we don't have enough graduate students, period. We don't have an abundance of foreign students. The 40 percent or these high percents that are being given out, that isn't disturbing me. What is disturbing me is there is not enough of any of them. Those gradu-

ate students who come over here, a goodly portion of them do stay. In the absence of them, the teaching faculty situation is going to be even worse.

Mr. DUNN. I would agree with that. People tell me we won't lose them.

Mr. GAITHER. The problem is we don't have enough of any of them.

Mr. DUNN. We aren't going to lose any, but maybe gain $2,000 per student, $1,600,000 extra cash. You haven't made an argument against that kind of a program.

Mr. GAITHER. That's probably a good idea, except for one thing. If they are the only graduate students available, they are not going to be paying it, anyway. With the exception of those directly supported by industry, they are not paying their own tuition, anyway. They are being paid by the research contracts that we are working on.

You are right. Charging $2,000 more, that might do something. It will reduce probably their numbers somewhat. That has to be done institution by institution.

Mr. DUNN. I said it was a nongovernmental solution.

Mr. GAITHER. If you are MIT and you say I don't have enough graduate students here, so I'm going to get them from anywhere I can because if I don't, Stanford is going to take over the operation and get more Government contracts than we do. It is competitive.

Mr. DUNN. Do you like the idea of the American taxpayer subsidizing foreign students?

Mr. GAITHER. No.

Mr. GEILS. Your notion has been tried sporadically around the country. A year ago at MIT, a large number of Iranian students applied for admission during the height of the hostage crisis. The MIT people were concerned. They said we will admit them. They are qualified intellectually and by training, but we will double the tuition.

They did double the tuition and they paid it, and it came from their Government and they were admitted. The major problem is that industry can cope with inflation and the university system cannot. We can go out and compete for the bachelors degree candidate and get the starting salary up to $25,000 a year. But, the State universities like Michigan and the University of Florida, they don't even pay $25,000 a year to an associate or assistant professor.

Mr. DUNN. These are Michigan State figures. These students are there right now. Michigan State University, one university, $1,600,000, divided among the professors. We could pay one guy the $1,600,000. [Laughter.]

Dr. FROSCH. I wanted to make one comment. I do not know how this applies to the situation in Michigan. But, a number of deans of engineering and State universities have voiced the complaint that part of their difficulty is the extent to which the operation of the engineering school is tied to the same detailed rules of operation as the rest of the university, and in fact, tied by the statutes of the State legislature, so that faced with the possibility of innovative schemes like that, in some cases they are in fact statutorily barred from charging different students at different tuition rates.

But perhaps more important than that, they are likely to be barred by the rules of the university and the legislature from paying different faculty members of the same rank at different rates. That is, as I mentioned in my written testimony, universities tend to take a Gertrude Stein kind of view that "A professor is a professor is a professor."

Therefore, they may not make distinctions between those in different departments. Of course, this tradition has been broken with regard to medical and law schools, but, it still holds with regard to other faculties and can be a particular problem in State universities.

Mr. DUNN. You will never get an argument from me that there is too much government in education. I have no problems with that argument.

Mr. BROWN. May I elicit the support from the members trying to maintain the schedule the chairman set? I'm trying to call on the members in order.

Mr. SKEEN. Mr. Chairman, I want to commend the panel. As an engineer, you have covered the whole gamut of problems that have been apparent to a lot of us that are interested in this field. You covered them very well.

I would like to start off, and I will do this quickly, Mr. Chairman, asking General Marsh to repeat for me again what the shortfall or the comparative figures were between the Soviet production of engineers versus—I heard you say 300,000?

General MARSH. That is correct, sir, 300,000 per year.

Mr. SKEEN. Then you said that was five times what we do in the United States. Somewhere along there, I don't remember, I thought we were producing 2,000.

General MARSH. Those, about 58,000 to 60,000.

Mr. SKEEN. I have one comment to make. I think we touched on it late in the discussions. It is always interesting to hear, "is there a policy that we have developed?" I don't know what kind of a contribution that is to you folks in professional engineering.

We had a policy on energy, and we haven't done anything about that. We had a policy on welfare and haven't eliminated all the poverty problems. We have probably added more to the burden than diminished it.

From what I gathered from the discussions, we have got more of a problem with education, basic education. I had written those words down when Dr. Frosch had begun his testimony because for a long time, it has been apparent to a lot of us that our educational system does not provide the kind of background that gives a student the option to choose whether they want to go into this kind of a field or not.

We want the students and we take a lot of the students from outside of the country. But, a lot of our youngsters are not equipped to make the option to take this step into the engineering vocational field. We are losing them because they are not equipped to handle it. They look over the curriculum and it is tough because the requirements in some of the basics, including some of the sciences, and we don't require them any longer. I wonder if we ought to back off and start with an educational policy. What do you think of that approach rather than talking about some specific

policy coming from the Congress involving the production of engineers?

Mr. GAITHER. I think I agree very much with you there. It is not so much a stated policy as it is a level of understanding or philosophy that pervades the entire educational system. I think we have gone though an era and may still be in it, in which technology and engineering, which is so associated with technology, is suspect by everybody.

I ran into that a very short time ago when I was trying to suggest that some of the turnaround and increase in productivity could occur as a result of increased work in robotics. I was asked whether I checked this with the unions. I hadn't, I must admit that. I probably should have because there are a lot of people that simply believe robots are only going to put people out of work.

Where we are right now is that if we don't have those robots, we are not even going to be in the automobile business at all. It is a matter of survival.

With regard to the preparation problem, we might ask ourselves the question why 50 percent of the students that start off as freshmen in engineering drop out at the end of their sophomore year?

We haven't answered that question. They are coming unprepared. That's quite right. They can't handle the physics and the chemistry.

Mr. SKEEN. Just the mathematics. We are producing cash registers right now that tell people how much change is due because we didn't teach them to make change.

General MARSH. One has to start with public support. I believe it is the parents, it is the school board, and you have to have a beginning to force that educational system to satisfy the needs of the society. So, I do not know that you can plug right into the middle of the educational system and solve our problem. That's what I was speaking of in terms of the commitment and public understanding.

Mr. SKEEN. I think you are right. I think you are far too late in the middle part of the program trying to plug this into the system. A graduate engineer is way too late. The problem is with our educational system, not just our technological system, and I couldn't agree with you more.

For a long time, anybody who had connection with engineering or technology was suspect because you are the evil geniuses of our society and you are automatically suspect and we have denied our own technology. The field of robotics, as you have mentioned, as far back as my time when I considered myself past prime in the late 1940's, early 1950's, we were talking about robotics and the whole new era of computer technology.

We fell way off of it. We are the innovators of more technology than any nation in the world and we seem to take the least advantage of it.

I thank the panel.

Mr. BROWN. Ms. Schneider?

Ms. SCHNEIDER. You made a request for appropriation of funds and something like a team effort between industry and the academic community in order to improve education in the engineering

field. I was curious if you had some idea as to where we might get those funds.

Mr. GEILS. A lot could come from industry, we would hope. We think some would come perhaps through these grants from NSF. There are some large State universities. We hope to get the State governments and legislatures to appropriate funds for running these programs.

I heard yesterday that the assembly in New York is going to work with industry in the State of New York to improve the quality and quantity of engineering education.

Where does the money come from? It comes from the people, one way or another.

Ms. SCHNEIDER. A number of us were getting concerned that you were looking too much toward Congress, and our pockets are empty about now.

Mr. GEILS. I understand that. I tried to say that. I guess I didn't say it successfully.

Ms. SCHNEIDER. What is really required as far as prioritizing engineering as a national goal would be obviously the power of the media. It is impressive. If the American Association for Engineering Education were to put on a media campaign in conjunction with industry and let those people know that there is a future and a need in the engineering area, I would think that it could go a great distance.

Now we seem to be floundering. I personally am looking for solid solutions.

Mr. GEILS. So are we.

Ms. SCHNEIDER. Thank you, Mr. Chairman.

Mr. BROWN. I call on Mr. Evans for any questions.

Mr. EVANS. No questions.

Mr. BROWN. Mr. Fish?

Mr. FISH. No questions.

Mr. BROWN. Mr. Gore?

Mr. GORE. Mr. Chairman, just briefly, I would like to thank our panel. I was here for the beginning of their presentation and had to leave and came back. So, I won't ask questions. But, I was very impressed with the statements that were presented and appreciative of the amount of time that each of these individuals has spent on this enormous problem.

I hope that our committee can help you in finding some sensible solutions for it. It is a much more serious problem than most Americans really realize. We have got to work together to solve it on a high priority basis.

Thank you, Mr. Chairman.

Mr. BROWN. Although I very much regret having to terminate the questioning of the panel, I think in fairness to our additional witness, we need to. Gentlemen, let me thank you very much. On behalf of the Chairman, who is presiding over the House, we thank you.

We will want to maintain close relationship with each of you in following up on this very important problem. Thank you very much.

I would like to call Dr. Lewis Branscomb next. He is a very distinguished scientist with a long career in government and indus-

try, one who occupies a key role in the science and engineering policy matters that we are discussing.

STATEMENT OF DR. LEWIS BRANSCOMB, CHAIRMAN, NATIONAL SCIENCE BOARD

Dr. BRANSCOMB. Thank you, Mr. Brown.

I come here today primarily to talk to you based on my experience as vice president and chief scientist of the IBM Corp. My responsibilities are to guide the scientific and technological strategies of the corporation in light of our long-term needs. That includes a lot of engineering activity.

The National Science Board, in substantial measure in response to stimulation from you, Mr. Brown, has focused much of its effort in the last 2 years on the National Science Foundation's responsibilities in engineering. This committee is well aware of the reorganization which created the directorate for engineering to devote full attention to engineering and its associated issues.

Our board's membership includes a number of distinguished engineers, as well as scientists with industrial experience in the management of engineering.

The board issued a policy statement, a general guidance on science and engineering education, last June and approved an implementation plan provided by the NSF director which I would be happy to submit for the record. Of course, the Foundation can only implement this plan within the available resources, which are severely constrained and likely to become more so.

My experience is in a company which invests commercially generated funds to the extent of more than $1.5 billion a year. The great majority of it is invested in hardware and software engineering. My colleagues and I are aware of our dependence on the capability of our universities to attract, educate and prepare the people whose capabilities determine the strength of American technology. I have made five trips to Japan in the last 12 months, some of them with teams of experts, looking at the situation there.

We Americans should not copy their policies and institutions, but we would do well as a people to emulate their dedication to technological excellence as a key strategy in their quest for national security and economic survival.

I would like, if I may, to submit my prepared testimony as chairman of the National Science Board for the record.

Mr. BROWN. I would like to have you do that. It will be made a part of the record. I would like to have the previous report that you referred to, also.

Dr. BRANSCOMB. I would now like to speak to you as a private citizen.

The driving force behind our industrial performance is the economic environment. The President has placed highest priority on creating the incentives in the private sector for an aggressive commitment by industry to the creation of new jobs at home and economic competitiveness abroad. This economic plan, if successful, will create the potential for growth. It is going to take a sufficiency of well-trained, motivated engineers prepared to address the problems facing our country to achieve the benefits that we want from that economy.

There are serious supply-demand imbalances in the availability of skilled people today, especially in the electronics and information industries and in sectors of the energy industry. In our industry, we see an insufficient availability of adequately trained people, especially in computer science, microelectronics, software engineering and manufacturing engineering involving highly complex materials processing.

We need doctorates and masters degree people as well as baccalaureates in production and in development. The shortage today limits the growth rate of an industry that is creating 50,000 jobs a year in this country.

It is very important to remember that it is not only the manufacturers of information systems that need these people. Our customers also need them. Our industry cannot grow unless our customers have the technical capability to use the productivity engines that our industry manufactures and services.

If the capacity of the engineering educational system were sufficiently elastic, supply and demand would in time produce the needed numbers of engineers. But, there are three supply constraints. First is faculty shortages, of which you have already heard, deriving both from a sharp decline in the number of U.S. citizen doctoral candidates in engineering, and and also from the decreased attractiveness of a faculty career in engineering.

The second supply constraint exists because our secondary schools are not doing the job. There are people in this country who don't have the incentive or the opportunity to study mathematics, physics, and chemistry in high school. Finally, we have a falling population of young people entering the college age group, so we are going to have to do better with less.

But, I think the engineering manpower problem is primarily not so much a matter of numbers but of the quality and appropriateness of skills. I would like to emphasize the fact that in this country we have allowed the factory to become an institution of low prestige rather than one of respect. This is not true in Japan, where engineers often prefer a career in manufacturing rather than industrial R & D.

If we are going to beat our competitors in productivity, we need manufacturing engineers with production skills who know how to automate a plant and who know how to manage quality work. That calls for a broad range of skills quite apart from product innovation in the area in which we have done very, very well.

We need design skills for a broad range of middle sized companies that don't do much research. We hear talk about what industry can do for the universities—generally meaning large enterprises that have big R. & D. establishments. There are also hundreds of thousands of substantial companies in the United States that employ large numbers of people who do absolutely critical engineering but don't do research. We don't hear much from them and don't do much for them.

We must also plan for a growing demand for engineering talent because we have to look to our defense technology. The last time we made large investments in our strategic weapons technology, we did it in the wake of the shock of the Soviet Sputnik. We had a concurrent massive Federal investment in our educational institu-

tions, increasing our science and research for a time at 10 to 15 percent annual real growth.

Today, we must find a way to provide for the needs of private industry while at the same time meeting the needs of our defense preparedness. Both are going to put demands on our engineers. Now, we are going to do it with decreased resources rather than increased ones. So, I think every American has his work cut out for him.

What can we do about it? Universities need a lot of help. There is no escaping the fact that they could do a better job, even with what they have. First, I will point out that in most engineering schools, attrition is a serious problem. The chances are only 4 out of 10 that a freshman enrolled in engineering will make it to a B.S. If we could motivate, train and help those students better, we could double the output of engineers with the existing establishment. We could do a better job of attracting women and minorities into the engineering schools.

In the critical shortage areas, universities must receive help from Government and industry. There are a surprisingly small number of universities in this country that can boast a fully staffed, research-experienced computer science and engineering program.

Youngsters today who are infatuated with computers are going to go to college assuming that the university will be ready to challenge them in the new information technology. I question whether either the fellowship support or the faculty skill and members will be there to meet the coming demand, since today's students interest in computers already outstrips capabilities of many faculties.

Universities must be able to offer competitive career prospects for the faculty and do it with new equipment that is relevant to the industrial experience students will have later. Access to research programs and competitive compensation are both important parts of the needed faculty environment.

What can industry do? We can do a lot. We can invest in training our own people, as we do today. This is a little known but very important contribution to engineering education in the United States. We can share our problems and talent with universities in joint research—a rapidly growing area. There is much experimentation with modes of collaborative research between industry and Government today.

We can make our special industrial capabilities available to universities. Companies can make special equipment available, as IBM recently did in donating a unique electron beam tool for microelectronics research to Rensselaer Polytechnic Institute. Faculty loans and sabbaticals are a way to bring skilled people from industry with contemporary experience right onto the campus to teach.

Finally, there is fellowship and financial support. We hear good news. Exxon will provide 100 doctoral fellowships in 3 years and research grants to 100 departments for 5 years. Over the last 3 years, IBM has provided 278 fellowships in science, mathematics and engineering, and will make 180 $25,000 departmental research grants in the 5 years 1980 to 1984.

But there are limits to what it is realistic to expect from industry. In spite of some of the hopeful comments made by the panel, the dollars are not there in industry to replace Federal dollars. Total industrial educational philanthropy is only 2.4 percent of the operating costs of our major private universities. Double that figure and that still leaves 95 percent of the money to come from elsewhere. Secondly, too much dependency of the wrong kind on industrial support will destroy the proper focus of university research in the long-range, the high-risk, the work of unpredictable but potentially enormous value.

I think industry, if it is very careful, can mitigate that danger and can keep it away for quite awhile. But if you push too hard on forcing the universities to survive at the hand of industry, it is a real risk. Industry will sometimes be able to move very swiftly to get new university capabilities started, as has happened with six or seven major microelectronics facilities at different universities, often with State government support, as in California and in North Carolina. But industry is not going to be able to sustain the operating costs of those facilities indefinitely. Industry will get it started, carry it for a few years, and then assume that more dependable and committed sources of support will carry those programs on.

In conclusion, I think it is going to take a committed effort by Government, universities, and industry, sustained through good times and bad times, to achieve the levels of technical performance of which this Nation is capable and which our people deserve.

Thank you.

[The prepared statement of Dr. Branscomb follows:]

Statement of

DR. LEWIS M. BRANSCOMB

Chairman, National Science Board, and

Vice President and Chief Scientist of IBM Corporation

before the

Committee on Science and Technology

U. S. House of Representatives

October 6, 1981

Mr. Chairman and Members of the Committee:

I am Lewis M. Branscomb, Chairman of the National Science Board and Vice President and Chief Scientist of the IBM Corporation.

It is my pleasure to appear before you this morning to discuss the adequacy of engineering education for America's needs in the 1980s. These hearings are particularly important because engineering skills determine--to a major degree--the productivity level of the U.S. manufacturing industry and the translation of scientific discovery into commercial innovations. The President's economic policy can create the incentives in the private sector for an aggressive commitment by American industry to the creation of new jobs at home and economic competitiveness abroad. But it will take well trained and highly motivated engineers--available in sufficient numbers--to translate this nation's potential for growth into reality.

By now most Americans are familiar with the facts about the U.S. competitive position in relation to other nations with whom we trade. I know of no better summary of this situation than Peter G. Peterson's study entitled "The U.S. Competitive Position in the 1980s - and Some Things We Might Do About It," published this year by the Bank of America for the Center for International Business. Many of the discouraging trends he observes--our low rate of capital accumulation, our declining portion of GNP invested in research and development, our aging stock of equipment--are causes of a declining level of technological performance.

Other indicators, such as a falling U.S. share of patent filings, a declining productivity rate and declining share of world trade are symptomatic of it. Many of these problems are primarily economic in origin; others may owe more to the superior efforts of our competitors than to a decline in our own performance. Nevertheless, if we succeed in reversing the economic decline and generate the capital and the business confidence to invest in technology to improve productivity to bring down inflation, we will need an even more robust engineering capability than we have had in the recent past.

Yet, we hear on all sides that U.S. engineering is in a state of crisis. What are the facts? Let me summarize briefly what I believe them to be, then expand on a few of them and close with some suggestions on what universities, businesses and government might do about it.

(1) There are today real shortages in a number of engineering fields, evidence for which is found in unfilled recruiting goals in industry, rapidly escalating starting salaries for baccalaureates, and declining graduate enrollments. While engineering graduates are only 8% of college population, they receive 65% of the job offers. In an appendix to this statement, I have provided the most recent data from the Division of Science Resources Studies of the National Science Foundation on current labor market conditions for scientists and engineers.

(2) Projections of industry needs generally exceed the supply by a significant factor, while new U.S. engineering graduates are expected to increase by only 10% in the next decade according to the National Center for Educational Statistics.

(3) Many of us in industry, looking at the people we are hiring, are concerned that the engineering population will not be adequate because of the decline in high school enrollments in science and math, and declining availability of such instruction.

(4) Another threat is found in a significant drop in U.S. students obtaining doctorates in engineering which threatens to jeopardize the availability of sufficient numbers of faculty in engineering. There are today many unfilled faculty positions. Estimates range between 1,600 and 2,000 or about 8 to 10% of the total engineering teaching faculty in the United States. In computer science the numbers of vacancies are smaller, but the percentage is even more serious. The fears are that this deficit in faculty will result in an overall deterioration of the quality of engineering education.

Engineering doctorates awarded reached a peak of 3,774 (773 foreign nationals) in 1972. The number has drifted downward to 2,751 (982 foreign nationals) in 1980, a decrease of 1,232 engineering doctorates awarded to U.S. citizens--a 41% drop. Thus, about 1,769 new engineering doctorates were available in 1980 for all industry, government, and academic institutions. Industry clearly has the greatest flexibility in setting starting salaries and in competing for the services of these students. The availability of up-to-date equipment is also a positive factor in favor of industry.

(5) Many are concerned about the quality of training many engineers receive, as a result of inadequate faculty, obsolete instructional equipment, and lack of contact with the technologies practiced in the most advanced companies.

Many people in industry feel that U.S. engineering education overemphasizes preparation for careers in research and development at the expense of training in design for manufacturability, design and production automation and manufacturing engineering--all areas vital to achievement of high quality, low cost products in American industry.

The facilities required for instruction in advanced design automation, process control or complex fabrication technologies are not only expensive and become very rapidly obsolete, but engineering faculties generally lack experiences in these areas.

Where shall we lay the causes of these trends? They surely start with a decline in the motivation of our young people to take up intellectual pursuits in general and science and engineering

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specifically. This problem is not only a problem in our schools, but is a part of the societal attitudes that gave us a "me" generation in the 1970s, which Daniel Yankelovitch tells us has become the "gimme" generation of the 1980s.

It is very difficult for young people to commit themselves to the expense of a doctorate level graduate training. The temptation of those B.S. graduates in shortage categories to take high paying jobs instead of getting additional training is understandable. But it is short changing both the universities and industry in a time of rapidly escalating technical complexity in modern design and manufacturing processes.

Young faculty are leaving for industrial careers in increasing numbers, in part because of substantial differentials in compensation. But I suspect that much bigger reasons are lack of facilities and resources in the university to do competitive technical work, uncertainty about the outcome of a 10-year quest for tenure and a growing overload of teaching duties and a diminished prospect for research support. In sum, technical careers in the university are simply no longer as attractive as once they were.

Now there are observations about these facts that need to be made. First, the best of our engineers are superbly trained, and some of the best training is found in smaller, specialized technical universities, in addition to the great institutions most widely known to the public.

A highly talented, well motivated graduate, trained in the most modern areas of engineering with the latest equipment, is much more valuable, and is productive sooner, than his fellow

student from an overcrowded, understaffed, poorly equipped, out-of-date institution. You cannot equate their value by counting numbers. Thus the supply and demand picture is deeply entwined with the matter of quality--how bright and how well equipped with skill and knowledge they are. In a time of serious financial stringency our schools, our research and fellowship-funding agencies and our employers cannot afford to stray from priority attention to giving opportunity to the most promising students and faculty.

Next we should admit that we do not necessarily need to expand the capacity of our universities in view of the fact that in some fields of engineering attrition from entrance to the B.S. degree runs 40%. Furthermore, we can still expand the talent pool from whom to draw by removing obstacles and disincentives from the path of bright young women, minorities and others who are today needlessly discouraged from pursuing technical careers.

We should also be sensitive to the danger of downgrading the training and job assignments of engineers by using them as technicians, to compensate for the lack of adequate institutions for technician training in the U. S.

What can be done to address these problems?

First, let me express a personal view that the problems must first be addressed with the academic community. Government and industry can and must help, but the faculties must gain conviction on the kind of engineering that should be taught, the kinds of research that they should do and look to the guidance of their students into the most promising careers. Universities should

seek the advice of industry and the support of government, but industry and government cannot dictate the solution to their problems.

Industry, on the other hand, has a real responsibility to help by:

- expanding cooperative programs for:
  - student work/study employment
  - faculty sabbaticals in industry
  - cooperative research and engineering problem-projects solving with universities
- assisting through:
  - faculty loans
  - participation in advisory and degree committees
  - short courses and lectures
- donation of equipment and loan of unique facilities
- and, assistance to students through funded fellowships in critical fields.

We are beginning to see quite a lot of welcome activity in many of these areas. Most of the new microelectronics centers in our universities are being initiated with primarily private and state resources.

In the past three years, my own company has awarded 278 graduate and predoctoral fellowships in mathematics, science and engineering. In the five-year period from 1980-1984, we will have made 180 grants to university departments in the amounts of $25,000 to support new science and engineering initiatives of the department's own choosing.

Exxon Education Foundation recently announced a $15,000,000 engineering education program. Exxon will fund 100 engineering doctoral candidates over a three-year period at 66 colleges and universities. In addition, 100 university departments of engineering will receive $20,000 per year for five years for salary adjustments of newer professors who might otherwise be lured away from engineering education by higher paying positions. However, we must not assume that corporate foundations can solve the universities' financial problems. At best, they can demonstrate effective modes of support and share their own technological problems and experience with faculties and students.

The Federal Government has been a major source of stimulation of engineering research with universities, primarily through the mission agencies.

The problem of funding engineering research is not, however, just a matter of adequate financial resources even though that is a critical problem for most of them. Faculties and students must have the opportunity to work on the most important problems facing industry as well as meeting the pressing needs of national defense. We should try to find more effective ways to give faculties access to the kinds of problems industrial scientists and engineers face in a cost-sensitive market economy.

NSF REORGANIZATION

The National Science Board has focused increasing attention and priority on engineering during the last two years. A recent reorganization of NSF resulted in a substantial organizational improvement for support of engineering research by NSF, and a Directorate for Engineering has been established. Engineering has an equal voice with the sciences in NSF management councils. Basic and applied research across a broad spectrum of engineering disciplines will be supported by the Directorate. The objectives of the Directorate are to strengthen engineering research and advance fundamental knowledge of engineering principles that can be applied to a large variety of devices, systems and processes; to stimulate the application of engineering results; to help ensure long-range improvements in high technology areas and to increase U.S. productivity.

In regard to applied research, the National Science Board has created a subcommittee on Applied Research. The purpose of the subcommittee is to watch over the coordination and management of applied research throughout the Foundation. Dr. Joseph Pettit, President of Georgia Institute of Technology, is chairman of the subcommittee. Formation of the committee stems from the importance that the NSB places upon integrating applied research into the basic research activities of the Foundation.

There are several activities of the Engineering Directorate that bear upon the problems that I have outlined above. I would like to mention one. Young engineering faculty members often find

getting started in independent research difficult in competition with established engineers with a documented track record. The Engineering Research Initiation Grant Program helps newly appointed faculty members get started quickly.

A variation of the Research Initiation Program starting this year permits individuals inside or outside of universities and who are candidates for engineering faculty to apply for a grant before accepting an engineering faculty position. Awards will be made to them upon acceptance of a faculty position. The objective is to attract highly qualified engineers into academic positions, some of whom have practical work experience in industry.

We must not focus our attention exclusively on counting noses and matching them to extrapolated estimates of industry's hiring needs. Today there are real shortages; tomorrow the supply of engineers may fulfill the numerical demand. But there will never be a surplus of highly talented people whose training and experience have not been allowed to become obsolete.

To insure the best performance from our engineering community and, therefore, from our economy, we must insist that we provide our best secondary and college students with access to a quality education, that the engineers have experience on the most modern equipment, and our faculties engage in creative work at the cutting edge of the application of the latest in scientific knowledge to the most challenging of human problems. Engineering schools, industry and government must work together to insure that this happens year in and year out in spite of the fluctuations in economic health and in current numerical demand for labor. This is an investment in our future, and there is no substitute for doing it right.

ATTACHMENT

DIVISION OF SCIENCE RESOURCES STUDIES
NATIONAL SCIENCE FOUNDATION

September 1981

CURRENT LABOR MARKET CONDITIONS FOR SCIENTISTS AND ENGINEERS

NSF has currently a survey of several hundred employers in the field. By late November, broadly representative information will be available on: the occupations in short supply, in balance or in surplus by degree level, industries of employment, region; perceived reasons for the problems; and adverse effects on employers. In order to develop interim information, interviews were conducted in July-August with 21 large companies (employing an average of 3,000 S/E's each), representatives of science and engineering professional societies, and staff of the Office of Personnel and Management. In addition, empirical data were examined including employment growth, unemployment rates, state employment services' job vacancy listings, College Placement Council recruitment activities and salary data.

The following assessments, therefore, may not be truly nationally representative but do show the current situation as perceived in a good sample of large high-technology companies. It should be recognized that data were not available in many instances for all degree levels, sectors of employment, or fields of specialization within broader categories.

OCCUPATIONS IN SHORT SUPPLY

Engineers

There are currently shortages of engineers in several fields of specialization. Private industry employers are having major difficulties in filling their requirements for computer, electrical/electronic and chemical engineers. Employers report some difficulties in recruiting mechanical, industrial, petroleum and mining engineers. There is evidence of an oversupply of civil engineers, and a balance for aerospace engineers.

There is an acute shortage of Ph.D.'s for employment with universities and colleges, with unprecedented numbers of unfilled faculty vacancies caused by a movement to industry and a decline in the numbers of new Ph.D.'s.

Computer Specialtists

By all accounts, there are widespread shortages of computer specialists. There is virtually no slack in the supply with unemployment at a very low .5 percent. The college and university sector is particularly hard-hit due to new Ph.D.'s preferring higher paying non-academic employment and the movement of experienced faculty to industry.

Statisticians

There are probable shortages of statisticians at all degree levels. Demand is particularly high for those in computer applications. College teachers are in short supply.

Mathematicians and Operations Researchers

There are not enough Ph.D. mathematicians to fill the current demand, a large fraction of which is to alleviate shortages of computer scientists in industry. Shortages are particularly acute for applied

mathematicians and operations researchers. Colleges and universities are having a hard time filling faculty vacancies. The market for mathematicians below the Ph.D. is, in general, soft.

OCCUPATIONS IN BALANCE

Chemists

The market situation for chemists seems to be generally in balance. There has been no perceptible growth in total employment between 1980 and 1981. The American Chemical Society reports that for Ph.D.'s the unemployment rate is less than 1 percent and there are fewer graduates doing postdoctorals as a "holding action." The high demand for chemical engineers has been filled, in part, by employment of chemists.

Physicists

There seem to be good employment opportunities for BS- and MS-level graduates as well as Ph.D.'s and the job market for physicists is generally in balance. There are some shortages reported in the specialties of vacuum science, physics/engineering, optics, acoustics and medical physics. Computer science and engineering jobs have absorbed some physicists; and shortages of secondary school science teachers are developing as a result of outflow to industry.

Geologists/Geophysicists

The job market for geologists and geophysicists seems to be in general balance with good demand for most kinds of specialists with Masters and Ph.D. degrees. There may be surpluses of personnel in other earth science fields.

Meteorologists

The market for meteorologists is in general balance. The Federal Government employs about two-thirds of all meteorologists. OPM reports a balance in supply of applicants and jobs. However, with Government growth at a standstill and private sector job listings falling, there may be some surplus developing in the near future.

Psychologists

All reporting sources indicated a general balance between demand and supply for Ph.D. psychologists.

Economists

There has been a growth in demand for economists over the past year and a probable balance in the supply and demand at this time.

SURPLUS OCCUPATIONS

Biological Scientists

There is a surplus of experimental and general biologists with two exceptions - demand is high, but being satisfied, for molecular biologists for genetic engineering research, and a shortage of Ph.D. chemical laboratory workers for hospitals.

Sociologists and Anthropologists

The market is mixed with a probable surplus of theoretical sociologists and anthropologists. There are reported shortages of applied sociologists and a balance for applied anthropologists.

Mr. BROWN. Thank you very much for that very good and stimulating statement.

Let me ask you this: The previous panel indicated, particularly General Marsh, that perhaps the first and most important ingredient in resolving this problem must be the national commitment to achieve the technological and technical excellence which would support our national security.

Would you agree with that?

Dr. BRANSCOMB. I agree with that, certainly.

Mr. BROWN. Do you see any reason why this administration and the leadership that we have, extremely able and competent people, would have any reluctance to commit this Nation to achieving that?

Dr. BRANSCOMB. The only basis I could see for being reluctant to commit the Nation to that goal is the lack of power that our political leaders have to commit the Nation to a goal. I believe that those in positions of national leadership have a responsibility to speak out on their vision of what the Nation can be and what it can do. But I think the task of creating a national consensus is more than making a plan or establishing in law a goal, even though that is valuable.

I am not even sure what comprises a national consensus. I don't think the Japanese did it by having someone announce the goal. I think the consensus was there in the Nation. I am less pessimistic than some of the earlier panelists about the attitudes of our people about technology. There is evidence that our public have a properly suspicious and jaundiced view about excessive claims from the technical community. Nevertheless, I think this country is proud of its technology, proud of its innovation. If we are given the leadership to which the public can respond with those genuine feelings, I think we can create a de facto national consensus which can rally all the parties. It is not just Government's problem. I put the responsibility also at the level of industrial leadership where a good many companies don't act as aggressively as their own company's technical performance might well justify.

Mr. BROWN. I'm not suggesting that any one element is the only solution or key to it, but that perhaps it does begin with national leadership. We all ought to see our own leadership roles, here in this committee, the Congress, in the National Science Foundation, on the Board, and all others, including the professional organizations and industry, and we have had representations from all of these various points.

We do have to put the pieces together.

Dr. BRANSCOMB. I would observe that President Nixon issued a science and engineering message to the Congress.

Mr. BROWN. It was the first such message.

Dr. BRANSCOMB. That could be emulated.

Mr. BROWN. At the risk of embarrassing you in your role as Chairman of the Science Board, let me ask you if there is any possibility that the mechanisms that we have already established in law for the creation of commissions by the Board might be a vehicle through which we can begin to address this problem, reaching—not so much reaching—but formulating and disseminating

this national commitment in a more effective way than we have at the present time?

Dr. BRANSCOMB. I think it can be. The Board shares that view. Our policy statement which I referred to earlier specifically speaks to that issue. The Director, Dr. Slaughter, recommended that we initiate a commission on criteria for quality in science and engineering education.

Before launching it, we want to consult with Secretary Bell because he has just created a similar commission, and has some distinguished scientists on it. The statutory provision for commissions has the laudable characteristic that it directs the involvement of lay citizens as well as technical experts on such commissions.

I think that is something the Board will welcome and should take advantage of. Second, I would observe that the language as presently written could be construed narrowly to charter us only to address research. I would trust if we do undertake the commission in science education, the committee will agree that this is an appropriate exercise of this authority.

Mr. BROWN. I am reluctant to raise the point that some of the efforts which this committee has felt very strongly about, science and engineering education, the participation in a cooperative effort to upgrade the capability of the universities through enhancing their equipment needs and so forth has not been looked on very favorably by this administration.

I want to ask you if you feel that there is a possibility that we could to some degree elicit a change in the administration's view on some of these, if the matter is properly presented to the Executive Office?

Dr. BRANSCOMB. I think the question is most appropriately put to Dr. Keyworth and others. I remain optimistic that the administration's position is somewhat more flexible than some people might fear it is. I honestly believe that the administration is focusing its attention on the overwhelmingly difficult task of maintaining their defense priority and at the same time, balancing the budget. That is not an easy task. None of us would find that easy to accomplish. I fear that single-mindedness on that objective has deferred addressing in some depth the issues that you described. But, they must, I think, be addressed.

Mr. BROWN. I'm going to ask Mr. Harkin to take the chair at this point and continue with his questioning until we get a quorum for the business.

Mr. WALKER. I had some material I wanted to submit for the record. Mr. Chairman, recently, I had some material brought to my attention by the American Society of Civil Engineers which relates directly to the topic of the committee today.

I would ask unanimous consent that it be entered as part of the hearing record.

Mr. BROWN. Without objection it will be available from committee files.

Ms. BOUQUARD. Mr. Chairman, I ask unanimous consent to insert my statement in the record.

Mr. HARKIN. No objection.

[Statement by Hon. Marilyn L. Bouquard follows:]

October 7, 1981

REMARKS BY
HON. MARILYN L. BOUQUARD

ENGINEERING MANPOWER CONCERNS

Mr. Chairman. I would like to call your attention to the fact that the current job market situation for engineers might be seriously affected by the implementation of the recently adopted tax incentives for research and development. It is my belief that not enough consideration was given to the potential effects of the proposed tax legislation so that the tax provisions will exacerbate an already threatening problem. In order to make the seriousness of the problem clear, I will summarize for you what I have learned in contacting various associations of engineers and engineering educators.

Rapidly increasing demand for engineers has caused severe "compression" in salaries and that has been confirmed in these hearings. The spread in salary between experienced engineers and engineers fresh out of college is virtually non-existent. According to the National Society of Professional Engineers' most recent survey, THE MEDIAN INCOME OF ENGINEERS WITH THIRTY OR MORE YEARS EXPERIENCE IS ACTUALLY LESS THAN TWICE THE INCOME OF ENGINEERS WITH UNDER A YEAR OF EXPERIENCE. This imbalance is grossly inequitable and has detrimental implications. Secondly, there are more than two thousand vacant positions on the faculties of the nations engineering schools, and there is a severe shortage of engineering Ph.D.'s to fill these slots. Though the country should be producing nearly four thousand engineering doctorates per year in order to satisfy the needs of both industry and academia, only 2,800 doctorates are awarded each year. Of these, one thousand are foreign students, often under some obligation to return to their own countries after graduation.

THERE ARE TWO IMPORTANT CAUSES OF THIS PROBLEMATIC SITUATION. ONE IS THAT BECAUSE OF HIGH DEMAND FOR ENGINEERING GRADUATES, COMPANIES HAVE BID UP THE PRICE OF STARTING SALARIES. THE SECOND CAUSE IS THAT STIPENDS FOR GRADUATE ENGINEERING STUDENTS HAVE NOT KEPT PACE WITH INFLATION, OFTEN REMAINING AS LOW AS FIVE THOUSAND DOLLARS PER YEAR. THE INCREMENT IN SALARY ONE GAINS BY REMAINING IN SCHOOL FOR A DOCTORATE IS INADEQUATE COMPENSATION FOR THE COST OF REMAINING IN SCHOOL. IT IS EXTREMELY HARD FOR A YOUNG ENGINEER -- ESPECIALLY FOR ONE WHO HAS ALREADY BORROWED MONEY FOR COLLEGE -- TO FOREGO FOUR TO SIX YEARS OF THOSE EXTREMELY GENEROUS SALARIES THE COMPANIES ARE OFFERING. IF HE MAKES THAT CHOICE, HIS PEERS ARE GAINING VALUABLE YEARS OF EXPERIENCE AND SALARY INCREASES WHILE HE STILL REMAINS IN SCHOOL.

FIVE YEARS AFTER RECEIVING A B.S., AN ENGINEER EARNS AN AVERAGE OF $23,800. IF HE HAS ALSO RECEIVED AN M.S., HE WILL EARN $25,300. IF HE HAS FINISHED HIS PH.D. ALREADY AND IS IN THE JOB MARKET, HE WILL EARN $29,100. AFTER ANOTHER FOUR TO SIX YEARS, THEY WILL EARN AN AVERAGE, RESPECTIVELY OF $27,750, $29,750 AND $32,400. (THIS INFORMATION DERIVES FROM A REPORT ENTITLED "PROFESSIONAL INCOME OF ENGINEERS -- 1980" COMPILED BY THE ENGINEERING MANPOWER COMMISSION OF THE AMERICAN ASSOCIATION OF ENGINEERING SOCIETIES, NOVEMBER 1980.) A ROUGH CALCULATION SHOWS THAT IT TAKES NEARLY NINETEEN YEARS FOR A PH.D. IN ENGINEERING TO RECOVER THE ADDED COST (IN FOREGONE INCOME) OF HIS EDUCATION IN INCREASED SALARY. IF HE RECEIVES A $10,000 ANNUAL STIPEND AS A GRADUATE STUDENT, HE CAN RECOVER THE COST IN NINE YEARS. BUT MOST UNIVERSITIES CANNOT AFFORD TO AWARD THEIR ENGINEERING GRADUATE STUDENTS NEARLY THAT MUCH OF A STIPEND.

IN ADDITION, IF THE CURRENT SITUATION PERSISTS, THERE WILL BE FEW AMERICANS QUALIFIED TO TEACH ENGINEERING. WE WILL PAY DEARLY FOR THE EXTRA ENGINEERS BEING HIRED NOW AT THE BACHELORS DEGREE LEVEL WITH A SEVERE SHORTAGE OF ENGINEERS IN THE FUTURE. IF WE DEFER TO MARKET FORCES, PERHAPS THE SITUATION WILL CORRECT

ITSELF. BUT IF WE INTERCEDE CARELESSLY, WE STAND TO EXACERBATE THE ALREADY THREATENING SITUATION AND IT WILL BECOME CRITICAL.

THE RECENT TAX PACKAGE INCLUDES VIGOROUS INCENTIVES FOR INCREASING PRIVATE SECTOR SPENDING ON RESEARCH AND DEVELOPMENT, AND WILL ENCOURAGE A HIGHER LEVEL OF COOPERATION BETWEEN UNIVERSITIES AND INDUSTRY. DURING RECENT YEARS, INDUSTRY HAS PROVIDED LESS THAN FIVE PERCENT OF THE FUNDS FOR THE NATION'S COLLEGES OF ENGINEERING. IF THIS WERE TO INCREASE DRAMATICALLY ENOUGH TO OUTWEIGH THE DECREASES IN FEDERAL FUNDING, PERHAPS STIPENDS FOR GRADUATE STUDENTS COULD BE INCREASED AND ONE PROBLEM WOULD ABATE. SUBSTANTIAL INCREASES IN THE LEVEL OF INDUSTRY FUNDED RESEARCH AT UNIVERSITIES COULD ENHANCE THE ATTRACTIVENESS OF A UNIVERSITY CAREER IN ENGINEERING. HOWEVER, INCREASING THE DEMAND FOR ENGINEERS IN THE PRIVATE SECTOR BY ALLOWING TAX WRITE-OFFS FOR WAGES OF R&D WORKERS MAY RUIN THE UNIVERSITIES' ALREADY WEAKENED ABILITY TO COMPETE FOR BOTH B.S. STUDENTS FOR GRADUATE SCHOOL AND FOR PH.D.'S TO BECOME FACULTY.

IT IS VERY DIFFICULT TO PROJECT WHICH OF THESE EFFECTS WILL DOMINATE, BUT THE EFFECTS OF A SPECIFIC PORTION OF THE LEGISLATION ARE MORE PREDICTABLE. THE PROVISIONS INCLUDE A TAX CREDIT EQUAL TO 25% OF THE INCREMENT IN WAGE EXPENDITURE FOR RESEARCH AND DEVELOPMENT. COMING AT A TIME WHEN THE DEMAND FOR ENGINEERS ALREADY FAR EXCEEDS THE SUPPLY, THIS FEATURE WILL ENCOURAGE THE PRIVATE SECTOR TO BID UP THE SALARIES EVEN HIGHER. EVEN FEWER PEOPLE WILL CONTINUE ON FOR GRADUATE DEGREES, AND OF THOSE, FAR FEWER WILL BE WILLING TO REMAIN IN ACADEMIA. IN THE NOT TOO DISTANT FUTURE, THE UNIVERSITIES WILL BE UTTERLY INCAPABLE OF TRAINING AN ADEQUATE NUMBER OF ENGINEERS. INDUSTRY WILL SUFFER, AND SO WILL THE REST OF US.

GIVEN THIS PROBLEM, I ENCOURAGE MY COLLEAGUES TO MONITOR THE EFFECTS OF THESE PROVISIONS CAREFULLY OVER THE NEXT YEAR OR SO AND HAVE A BASIS FOR DECIDING WHETHER TO AMEND THESE PROVISIONS IN THE 98TH CONGRESS.

Mr. HARKIN. Mr. Gore?

Mr. GORE. No questions.

Mr. HARKIN. How is the quality of engineering education in the United States compared with that of Japan or West Germany or the Soviet Union?

Dr. BRANSCOMB. I think we have a more diverse educational establishment than most other countries. I don't think there is any question that the best of our educational establishment is far superior to that of any other nation at the university and postgraduate level.

The Japanese educational system is different in character. It is my impression that it is much less effective at generating imaginative, innovative people given to new concepts and ideas than is our own. Japan does focus very strongly, however, on production issues. They are committed to large numbers of students and have the advantage of an extremely rigorous secondary education.

That comment could also apply, multiplied by a factor of two, for the Soviet Union. They have very rigorous preparation prior to reaching the university level. They do not train people with the kinds of imagination and creative skills that our institutions do. I believe that those institutions in the United States that are properly staffed and equipped still do the preeminent educational job in this world.

Mr. HARKIN. Earlier this morning, when the hearing started, I was here briefly. There were two gentlemen that were with the Iowa State University. I didn't know it at the time, but one of the gentlemen is an instructor in the EE department, which, as you know, is one of the foremost engineering schools in the State.

This man was telling me on the way out that he was interested in the hearing. I asked him what he thought about this problem of engineers. He said that what they had seen at Iowa State, one of the problems they have seen was this: Engineers, the ones who really were at the top of the class, when they graduate, they are picked up by private companies in the United States who offer them not only very nice salaries, but also offer them sort of an in-house graduate program.

I didn't pursue it. There was an in-house graduate program, either they send them to school someplace else later on, or something of that nature. I was unclear on that. The effect of that was two-fold. One, he thought that the quality of graduate students they were getting was dropping.

And second, the quality of the instructors that they eventually got was going down. While they still have a good undergraduate program, the graduate program is suffering.

Do you have any thoughts on that?

Dr. BRANSCOMB. Yes. There are two kinds of activities in industry that fit the general description. Only one of them could have this effect. The competition for the most able young people is sufficiently severe that quite a number of companies are trying to locate the talent when they are undergraduates and prepare them to be recruited later.

There is, for example, a well-known program at Bell Telephone Laboratories in which Bell recruits people at the baccalaureate level. Then, immediately, they send them to graduate school at the

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company's expense to get a masters degree. Bell, in fact, emphasizes the educational levels required for modern technology by having a rule that no one in the laboratories at Bell Labs can be employed without a masters degree or a doctorate. But, they will help you obtain a graduate degree when they recruit at the baccalareate level.

In addition, there are other companies that allow employees, after years of work, to take time off at the company's expense to pursue a degree. My company has a systems research institute at New York City. We hire faculty from the university as part-time teachers. I don't think that activity has the effect you described, because it is exclusively for our permanent employees.

Mr. HARKIN. I have no further questions. We will end our discussion for the moment—we won't end it, but we thank you for coming today.

Dr. BRANSCOMB. I would like to thank you for the opportunity to appear.

Mr. HARKIN. Dr. Frosch, thank you for coming back again.

That will bring to a close this portion of the hearing on engineering manpower concerns for science and technology. The committee will now have a brief recess.

[Brief recess.]

Mr. HARKIN. We are honored to have our colleague from the other body, the Honorable Senator Harrison Schmitt, to testify regarding engineering manpower concerns.

STATEMENT OF HON. HARRISON SCHMITT, MEMBER, U.S. SENATE

Mr. HARKIN. Senator Schmitt, we welcome you to the committee. It has been my personal and professional pleasure to work with you in the past. We certainly look forward to your testimony.

We have a copy of your written testimony. We will include it in the record at this point.

Please proceed.

Senator SCHMITT. Thank you, Mr. Chairman and members of the committee. It is good to be with you again and so often. One of the exciting aspects of this year has been an opportunity to work very closely with this committee and its subcommittees in the refinement and design of not only science and technology policy, but also its implementation.

As the words of a song go, I have looked at science from many sides now, to paraphrase a little bit, not only as a trained scientist, geologist, but also as an applied scientist and engineer in the space program, and now, looking at the policy and political sides of science and engineering. I hope that some of my thoughts will be of use to the committee.

Mr. Chairman, this country is embarking on a major revitalization of our economy and strengthening of our national security. Success will depend greatly on our national innovative abilities and our skills in successfully commercializing these inventions.

Until recently, we have too often taken for granted the advantages we have enjoyed in science and technology and have allowed national policies and attitudes to develop which have tended to

undermine our capacity to innovate and compete successfully in the marketplace.

Mr. Chairman, since you have so generously included my full testimony in the record, I will move through certain parts of it and expand on them as seem to be fit.

Certainly, our tax, monetary and regulatory policies have discouraged the pursuit of innovative ideas in recent decades. That, I think, is something that we are all working to refine and to eliminate unnecessary tax and regulatory activity, where that can be done.

My Subcommittee on Science, Technology and Space has been looking in its areas of jurisdiction at some of the other problems that seem to have discouraged young men and women from moving into science and technological fields that are appropriate concerns of the Nation as a whole.

We have conducted oversight hearings on the National Science Foundation authorization. I have had field hearings in New Mexico, which is a major center of science and engineering activity now, in addition to being a growing area of business activity. The subcommittee and its staff have begun to concentrate on this fundamental issue of engineering and scientific manpower which I commend you for addressing also.

It is obvious that many of the problems have their roots in the difficulties of our elementary and secondary school systems which, in turn, may very well have their roots in the preschool teaching of our children. The very dominant influence of television in that preschool environment has not yet realized its beneficial potential.

But today, I think it is important to focus on what can we do in the near and intermediate term to solve the technical manpower problem while at the same time, we address the more fundamental generic difficulties that exist within our education system as a whole.

Everyone, I believe, is aware of how much more aggressive our international competitors are and have been for some time in the education of their young people, particularly in science and engineering. Japan, the Soviet Union, many other nations are doing far more in this area and recognize the importance in international economic competition of having a reservoir of young men and women who can serve their national economic interests in engineering and scientific careers.

In contrast, we have seen a diversion of our young talented men and women into fields of law, social sciences and other fields, which, while important in their own right, do not address the basic problem that is before the subcommittee today.

One might say that we have encouraged our young men and women to go into careers that treat symptoms of problems rather than solve problems—an important difference in science and engineering education versus legal and social education.

Again, I don't mean to degrade the importance of those other fields in any way. Nevertheless, there is a fundamental difference in the educational and professional discipline that the two general categories entail.

Another problem of which our subcommittee has become much aware of is a decreasing number of young persons going into under-

graduate engineering and science education over the last decade or so. Also fewer have been going further into graduate education to seek advanced degrees.

At the same time, industry is hiring away the holders of baccalareate degrees at unbelievably high salaries before they go into advanced degree work, as well as hiring away their professors.

In one sense, we are eating our seed corn and shooting our farmers. As a consequence, the most credible estimates of our shortfall are staggering. Our shortfall of advanced degree holders in science and engineering is approaching about 15,000 young people a year on top of an already clear deficiency of such degree holders.

The major and intermediate sized corporations, the intelligence community or defense community, or NASA, or any other agency or group that needs young men and women in engineering or science, already have a significant shortage of people today.

There are some signs that industry is responding to the challenge, although I still believe not nearly at the level they must. I don't see the Government investing the billion or so dollars a year in addition to what is already being invested to solve this problem of advanced degree work in engineering and science. That investment must come from the private sector, for the most part.

This does not mean that I feel there is no Government role. The role of the National Science Foundation in providing fellowships on a competitive basis in fields of obvious national interest is, I think, a legitimate function of Government, and should continue. But, it cannot ever be, in my estimation at a level commensurate with the public and private demands.

Industry is seeking new arrangements with our colleges and universities. We see this in New Mexico with an increased interest in supporting chairs for various science and engineering disciplines and developing more scholarships and work study plans in the university system with private sector investment.

I think the Congress has, by its recent tax code, offered further incentives and encouragement to the private sector to do this.

One other area that has come to light in our deliberations, particularly those in New Mexico, is the growing deficiency in this country in associate degree holders in science and engineering, very broadly defined.

In New Mexico, we have a totally inadequate community college system. We already have a projection of 10,000 new workers in the next 5 years in the Albequerque area alone, many of whom will need to have the associate degree for technical and craft work. We are not going to be able to supply them. That demand is going to have to be met from outside the State until we are able to build the kind of system that is necessary.

I am sure that is an example of a situation existing throughout the Sun Belt, as well as in other parts of the country, where the demand for technically trained and experienced young men and women will be going up astronomically as our economy begins to expand, as I believe it will, and as our demands for national security expand.

We have for some years now depended in part on the military services as a giant vocational training system. And where we have

developed in that system experienced, well-qualified young men and women in technical fields, industry has gone in and raided them at salaries three and four times the salaries the military can pay and the military is left without the trained manpower that is necessary for its mission.

Again, I do not think that we can deal with the military manpower problem in a vacuum. Some progress was made through increased salaries and benefits, but, Mr. Chairman, I would be less than candid if I said I thought the problem was solved. Maybe the best way we can solve this problem is to keep these trained military people in their National Guard units so that they are available to serve their country. A draft into the Reserves may well be an answer to many of those kinds of joint public and private sector problems.

Mr. Chairman, I appreciate this opportunity to meet with you and to discuss this problem. I will be happy to answer any questions that you or any other members might have.

[The prepared statement of Senator Schmitt follows:]

TESTIMONY OF

SENATOR HARRISON SCHMITT

This country is embarking on a major revitalization of our economy and strengthening of our national security. Success will depend greatly on our national innovative abilities and our skills in successful commercializing these innovations. Until recently we have too often taken for granted the advantages which we have enjoyed in research and technology and have allowed national policies and attitudes to develop which have tended to undermine our capacities to innovate and compete successfully in the market place.

Our tax, monetary and regulatory policies have discouraged pursuit of the uncertain and the dramatically innovative. I support the efforts which the Administration is taking in tax reform, stabilization of the money supply and elimination of unproductive regulation, all of which will improve the climate for innovation.

However, the most important influences on innovation are the imaginations and skills of the men and women who make the discoveries and transform them into usable goods and services. My Subcommittee on Science, Technology, and Space has held hearings this year on the problems of assuring that there will be enough of these men and women to address the needs of our nation. Our oversight hearings for the National Science Foundation examined the federal

investment in developing science and engineering manpower. Our field hearings in New Mexico addressed the requirements of high technology industry for skilled scientific and technical manpower and the efforts of the universities, the state government and industry to anticipate and respond to these requirements. My comments today reflect much of what we learned from these hearings as well as our continuing examination of the issues.

The manpower with which we are concerned will for the most part require deep understanding in the sciences or engineering, which in turn will rest on solid education in mathematics and science. Our problems originate in the earliest school years and are compounded through the educational process.

An estimated 5% of our high school students take no math or science courses beyond the 10th grade and math SAT scores declined steadily from the early 1960's through 1980. It is estimated that there are only 10,000 physics teachers in the nation's more than 15,000 school districts. Students are not only precluding the opportunities for scientific or technical careers but are even jeopardizing their abilities to function successfully in an increasingly technologically complex society. Until families, local school boards and state governments demand new curriculum requirements and academic rigor, major improvements are unlikely.

Beyond the secondary school level, our problem seems to be attracting the number of qualified, talented men and women needed by a technologically complex society such as ours and, almost paradoxically, providing the teachers to train and educate the rapidly growing number of students who are electing engineering as a professional goal.

There are many different estimates of our future shortages of engineers, ranging from an excess to shortfalls of tens of thousands. I don't know the answer, but I suspect that the demand will be higher than we are prepared to meet. I suspect this because of reports which I am receiving from industry, business, federal laboratories and universities, as well as the major challenges which we face in building up our national defense, developing alternative energy sources, capitalizing on the burgeoning biotechnology industry, achieving environmentally responsible economic growth, to name a few. I also know what our competition is doing, for example:

- Japan -- with a population roughly half ours -- grants as many engineering degress as we do.
- In the Soviet Union -- with a population half again as large as ours -- about five times as many students go on to engineering training as do in the U.S.

By contrast, we have been training more lawyers, than much of our competition combined. In some ways, it would seem that we have concentrated our skill on refining our slicing of the pie while our competition focuses on enlarging theirs, often at our expense.

It is also true though that students are now turning to engineering in record numbers and that there is a serious shortage of faculty to teach them. Estimates indicate that perhaps 2,500 out of 20,000 engineering faculty positions in this country are vacant. The problem is fairly clear -- industry salaries have been bid up to the point where too many of the best students simply cannot see the net advantages of an academic teaching and research career, or even in going on for post baccalaureate education.

While there are important governmental responsibilities in dealing with these problems, it seems to me that there are a particular challenge and opportunity for industry. Certainly industry has a major immediate stake in resolving our engineering manpower problems, since their future successes hinge in no small measure on the availability of motivated, educated graduates. At the same time there is an opportunity to reestablish linkages with the academic world which have weakened over

the last twenty or so years. The erosion of the former interdependence of the two sectors is attributable in some measure I think to the displacement of private sector aid for research and student support by federal funding. There is now an opportunity to redress the imbalance.

There seem to be signs already that industry is responding to the challenge. The National Society of Professional Engineers, the Association of American Engineering Societies, the Institute of Electrical and Electronic Engineers, the American Society of Mechanical Engineers, the Council of Scientific Society Presidents, the American Association of Universities and the National Association of State Universities and Land Grant Colleges are all, among others, actively examining the problems and alternative responses.

Industry, too is seeking new arrangements with our colleges and universities. The boldest initiative so far was announced three weeks ago by the Exxon Education Foundation, which will provide $15 million for 100 teaching fellowships and 100 salary grants for junior faculty in the engineering fields. Sixty six U. S. colleges and universities will be beneficiaries of this program. Further, the Foundation is responding specifically to the problem which industry demand for engineers is creating -- I quote, "The faculty shortage (in certain key fields of engineering) stems in part from the fact that industry is

hiring engineers immediately after they receive their bachelor's degrees at starting salaries that make graduate study and junior hiring faculty positions financially unattractive by comparison." This bold recognition of a problem and industry responsibility should and, I believe will be followed in different forms by more of our companies and businesses in the months ahead.

While much attention deservedly is being given to meeting the needs for university-educated engineering manpower, there is another equally important and difficult technical manpower requirement which we will need to solve -- that for skilled technicians and craftsman such as tool and die makers, machinists and electricians. Without these skills many of the best ideas of our scientists and engineers will not be translated into the new goods and services which we need.

Japanese companies traditionally train their own skilled technicians with confidence that these workers will be lifetime employees. There is no such tradition here. West Germany provides intensive apprenticeship programs, funded jointly by industry and government, for those who do not go on to the universities.

We have tended to use the military services as the training ground for this skilled labor, which industry raids as demand requires. The implications of this

arrangement are not reassuring at a time when we are simultaneously revitalizing our civilian economy and our national defense. It may be that this area of technical manpower will require the most imaginative attention of our industrial, educational, military and governmental sectors.

Much has been said about the federal responsibility for solving the engineering manpower problem, whether in terms of instructional and research equipment, student assistance or faculty salaries. The magnitude of the estimates of the assistance required though are well beyond that which the federal government can begin to provide. Also the shift toward less government regulation and other direct involvement, along with the return of more responsibility and resources to the private sector, will necessarily limit a federal role.

We examined the NSF science education programs during our oversight hearings earlier this year and concluded that ". . .programs in this area may be too fragmented so that the overall impact of the effort is limited. Nevertheless the problems of scientific and engineering education are all too real and pressing to abruptly and totally terminate the NSF program." Funds were provided in our authorization to continue the scientific and engineering educational activity at a basic level, with a clear recognition that

"The NSF now has an obligation and an opportunity to reexamine, redefine and reconstruct the science and engineering education programs." We will be exploring with NSF their plans before the authorization process begins for FY 1983.

I appreciate this opportunity to meet with you and discuss this problem, which we all agree is so important to the nation's successful economic and national security revitalization. My Subcommittee will be continuing its examination of how our future scientific and engineering manpower requirements can be met and will welcome your interest and participation.

Mr. HARKIN. Thank you very much, Senator, for a lucid discussion of this whole topic.

A couple of things you said struck me. In your testimony on page 2, you mentioned the high school grades. An estimated 5 percent take no math or science beyond the 10th grade. The math and SAT scores have steadily declined. I believe a lot of this starts in the early years.

When I went to high school in the 1950's, it was extremely important to take math, science, physics, and chemistry. In fact, I went to a small high school originally and the students were leaving there and going to another high school simply because that high school had a chemistry lab and ours didn't. I did the same thing, so I could take chemistry. The big thrust was on science at that time.

But now, it doesn't seem that way. When I visit high schools now, it doesn't seem like there are any teachers there that are interested in that. On the other hand, as I have said on this committee now for 7 years, we have seen the programs that the National Science Foundation has had for teacher education and science and engineering education over the last several years declining.

It seems like, as you say, we are eating the seed corn. I am informed by staff it went from $80.7 million to $9.9 million. That's science engineering and education. How do you get them motivated? If we are doing what we are doing at our level, cutting it out, how do you get them motivated?

Senator SCHMITT. Mr. Chairman, the educational services experiment in science and engineering and mathematics that was conducted in the 1950's and early 1960's by the NSF will probably go down in history as one of the most successful educational experiments ever conducted in this country.

It was not a dictation by the Federal Government. The NSF provided a curriculum development service, a teacher education service in response to the Soviet technology challenge in which the whole country responded. The NSF experiment, if you will, which we have largely abandoned, was very successful, in contrast to

some other regulatory activities of the former HEW and now Department of Education that produced antagonizes and were, I think, detrimental to the educational process.

Whereas, you apparently were a beneficiary of it. I came a little bit earlier. When I entered Cal Tech, I was almost overwhelmed by what I had not learned in the 1940's in science and mathematics. I survived that experience, barely, but recognized the inadequacies of my public education. I was very, very happy to see what developed in the 1950's and 1960's with NSF's activities.

In this area as well as many others, I believe that we have to get the Government away from focusing its resources on the regulation of education in this country, and toward providing services, such as those that we have provided in engineering and science, that the educational systems cannot supply themselves because of limited resources available to individual school boards, for example.

We conducted that experiment. It worked. I see no reason to have abandoned it in the first place. I see no reason not to go back to it as we approach this very, very critical problem in the future. I am a great one for looking at models of things that the Federal Government has done that have worked.

We, talked before about the extraordinary success of the research and technology program which the National Advisory Committee on Aeronautics began in 1914 and which was gradually transformed into NASA. That is something that worked. It also worked with agriculture in a completely different way that was appropriate to the agricultural demands of our country. But, instead of building an energy extension service on that model, we put it in the hands of the bureaucrats rather than in the hands of the land-grant colleges where it would have worked.

The Federal Government doesn't always do things wrong. There have been some things we did right. The NSF teaching development program in the 1950's and 1960's was one of the things we did very well. It had assistance from NASA and a lot of funds, which have now dwindled. But, the NSF programs, along with NASA really were a catalyst for vast improvement in our educational capability.

Mr. HARKIN. I agree with everything you said. I just hope we can get our authorization committees and the appropriations committees, to put the appropriate amount of money in there to get this thing going.

I would like to be an optimist, but I sound like a pessimist.

Senator SCHMITT. I'm an optimist. I think we are all smart enough to finally realize that these have to be done and we must adjust our priorities accordingly. That's one of the reasons why I hope that the Science and Technology Subcommittee of the Senate Commerce Committee can obtain some joint jurisdiction over NSF activities with the Labor and Human Resources Committee. Senator Hatch and I are discussing this. We haven't really figured out how to do it. Sequential referral would be perfectly adequate.

In any event we will continue to conduct oversight of NSF. I hope that we can get that shared authorization so that we can work with you in a joint jurisdictional relationship, as we do on most other science and technology issues.

Mr. HARKIN. Thank you, sir. Mr. Brown?

Mr. BROWN. Senator, I don't want to belabor your excellent statement. I have always been impressed with the balanced and reasonable approach that you take to problems of science policy, and I certainly include your statement.

What you have said confirms the statements made by our earlier panel this morning with regard to the complexity and seriousness of this problem and the need to approach it from a multitude of different angles, beginning at the earliest stages of training in mathematics and science to the engineering and technical fields.

One thing that struck me was the statement made very emphatically by General Marsh indicating his feeling that we can solve this problem if we made a national commitment to solve it. That is, if we recognized its importance to our total national security, to both our military security and our economic security.

This led me to feel that each of us in the roles that we play ought to contribute to establishing this national commitment in some fashion. I was led to raise the question whether we might be able to, through the existing mechanisms, the National Science Foundation, the National Science Board, we have, of course, Dr. Branscomb, who testified on that, and the science adviser to the President, if we couldn't take some new steps toward recognizing at the highest level the significance of science and technology and begin to fulfill this role of creating a sense of national commitment.

The question that I have for you to comment on is whether you see any possibility of a receptive atmosphere for this in the Executive Office of the President, in your relationships with Dr. Keyworth. I think Dr. Branscomb indicated that the Foundation would cooperate in seeking to do this.

There are mechanisms set forth in the Foundation's authorizing act, the organic act, for establishing national commissions in high-priority areas to address national problems. If we could, without creating some bureaucratic mechanism, use the institutions and personalities that we have, we could perhaps deal with this problem more effectively.

Would you care to comment?

Senator SCHMITT. I certainly would, Mr. Congressman.

Your question is extremely perceptive. No. 1, I have had conversations with Dr. Keyworth since the time when he was being considered for the science adviser and find that he also believes that this is one of the, if not the premiere problem that faces the long-term health of science, technology, our economy, and our military security.

So, I think there is very receptive ground in his office. I also believe that the President himself, is receptive. The President's history as Governor of California was one of great interest and awareness and understanding of what was happening in the major scientific laboratories of that State. I had that report from many different sources, and they are all very good sources.

I talked to him personally about this in December, and off and on since. I feel very strongly that he recognizes that the strength of this country is in the innovative capabilities of our individual people and our society as a whole.

Now, there are others in the administration who, in taking more of a bean-counting approach to budget cutting may not be quite as receptive.

I must emphasize particularly what it takes, in my opinion, to excite generations of young men and women in this country. In spite of the quality of the NSF-NASA education programs in the 1950's and 1960's, we must remember that Sputnik and the events around Sputnik excited a generation of young persons. No question about it.

The reason we got to the Moon, the reason that all of us returned safely, was due as much to the motivation of the young men and women who created and used the technology as to the technology itself. That's the essential ingredient and that's the reason why you have relatively less trouble going to the Moon than you do in building a Metro—one excites that energy of motivation and the other doesn't.

Whenever somebody asks you if you can go to the Moon, why can't you do something else, the reason is the key ingredient has not been generated by a John Kennedy, as somebody articulating something that the Nation is willing to do.

As I travel around this country and New Mexico talking to young people about science and space—which I still do more than I do about politics—that motivation is there and at the elementary and high school levels. There is a tremendous interest and awareness of science and technology, particularly in the last 5 to 10 years.

It seems to be another cycle where science, technology, and space are very, very exciting to young people. The reaction of young people to the Shuttle is extraordinary. I think probably it is as strong or stronger than anything that I saw in Apollo, although I was not as active out in the hustings with young people then.

So, I think we have very fertile ground. I think if we can find ways to provide the resources and the capability at the local level for science and mathematics training, there will be a very receptive audience. The question is how to provide the resources. I am less enthusiastic about a commission than I am about motivating students and teachers.

The most stimulating emotional influence that we have going for this country is the space program. It is not only stimulating and motivating for young people, it is absolutely essential to our future survival as a nation. I hope that in our conversations with the administration we can get a greater realization of the absolutely essential nature of our commercial and our defense involvement in space.

The President seemed to make it clear in his statement on strategic defense policy that he believes that that is important. I am not yet fully convinced that all the administration policymakers realize the absolutely essential nature of our involvement in space. This is one thing that could act right now as a catalyst to reversing at least temporarily the adverse trend in science and engineering education in the country as a whole.

Mr. BROWN. I won't belabor this further. I see nothing incompatible with the commission focusing on the overall problems and reaching the conclusion that some spectacular and dynamic and

exciting program such as space might be the magnet around which we can develop a program.

We might even come up with a new space policy act.

Senator SCHMITT. I did not mean to say the Commission would not have value, particularly for the public perception. If it is conducted in a public in which we and others can emphasize the importance of its deliberations and its conclusions, whatever they may turn out to be, then it can certainly serve as a seed for the kinds of things that I mentioned.

The ultimate result, as you have said yourself, is going to come from making these young men and women realize that the opportunities are there. We have so discouraged science and technology in this country since the heyday of Apollo; we have done everything we could to discourage science and technology. So that young people looking at the future are going to believe that there is no future for them in science and engineering.

Mr. BROWN. Thank you very much, Senator. I wish we had more time.

Senator SCHMITT. I do, too.

Mr. HARKIN. Thank you very much, Senator.

The subcommittee will stand adjourned.

[Whereupon, at 12:20 p.m., the hearing was adjourned, to reconvene at 9:30 a.m., in room 2318, Rayburn House Office Building, on Wednesday, October 7, 1980.]

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ENGINEERING MANPOWER CONCERNS

WEDNESDAY, OCTOBER 7, 1981

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
Washington, D.C.

The committee met at 9:40 a.m., in room 2318, Rayburn House Office Building; Hon. Don Fuqua (chairman of the committee) presiding.

Present: Representatives Fuqua, Winn, Brown, Dunn, and Weber.

Mr. FUQUA. Yesterday, we heard from a number of witnesses who outlined the extensive problems we now face regarding the engineering and technical manpower. I believe the evidence they presented underscored the severity of a situation that exists not only in our industry and universities, but as well within our military services. We also heard testimony of the need for a broad and comprehensive policy, as well as a national commitment to begin addressing these problems.

Today, we will be hearing from a number of important witnesses. They include Mr. Harry Havens, Assistant Comptroller General of the General Accounting Office, who will outline the current situation regarding the Federal role in engineering education and manpower.

Second, we are honored to have the respective presidents of the National Academies of Engineering and Science, Dr. Courtland Perkins and Dr. Frank Press, who will provide us with the perspectives of these two important organizations.

We regret that the Director of the Office of Science and Technology Policy, Dr. George Keyworth, will be unable to join us today. I understand a statement of the administration's view will be provided for the record at a later date.

Also, I would like to ask unanimous consent that photographs may be taken during the course of the hearing. Without objection, so ordered.

Our first witness will be Mr. Havens.

[The biographical sketch of Mr. Havens follows:]

HARRY S. HAVENS

Harry S. Havens was designated Assistant Comptroller General for Program Evaluation effective April 18, 1980. In this position, he is responsible for overseeing the operations of the U.S. General Accounting Office's Program Analysis Division and Institute for Program Evaluation. In addition, he is a member of GAO's Program Planning Committee, Assignment Review Group, Executive Resources Board, Budget Committee, and Information Policy Committee. He has additional duties involving overseeing the use of consultants in GAO's work and participating in the development of program evaluation training programs for GAO staff.

Prior to his present assignment, Mr. Havens was Director of the Program Analysis Division from 1974 to 1980.

Mr. Havens served in the U.S. Navy from 1957 to 1964 and with the Bureau of the Budget (now Office of Management and Budget) from 1964 to 1974. Before coming to GAO in 1974, he was Deputy Chief of the Human Resources Division of OMB and Chief of the Income Maintenance Branch.

Mr. Havens graduated from Duke University in 1957 with a B.A. in economics. He attended Oxford University, England from 1957 to 1959 as a Rhodes Scholar, receiving a B.A. in politics and economics in 1959 and the M.A. degree in 1963.

Mr. Havens received the Roger W. Jones Award for Executive Leadership in 1980, and the Comptroller General's Group Award for outstanding work on improving GAO effectiveness in 1979.

STATEMENT OF HARRY S. HAVENS, ASSISTANT COMPTROLLER GENERAL, GENERAL ACCOUNTING OFFICE, ACCOMPANIED BY MARY HAMILTON, GROUP DIRECTOR, SCIENCE AND TECHNOLOGY, GENERAL ACCOUNTING OFFICE; AND MICHAEL P. McATEE, SCIENCE POLICY ANALYST, GENERAL ACCOUNTING OFFICE

Mr. HAVENS. I would like to introduce my colleagues. On my right is Mary Hamilton, group director, Science and Technology. On my left is Michael McAtee, science policy analyst.

I have a fairly brief statement, but in the interest of time, I would propose to have that entered into the record and simply summarize the main points.

Mr. FUQUA. Without objection, the statement will be made part of the record.

Mr. HAVENS. We are pleased to be here to discuss our work, still in progress, on the Federal involvement in engineering education. We have three points that we would like to turn to today.

First, what is the nature and extent of Federal involvement in engineering education? Second, how will proposed budget cuts affect Federal involvement? Third, how does Federal involvement relate to current concerns about engineer supply, faculty shortages, obsolete instructional equipment, and curriculum focus?

Based on our interim work to date, our findings can be summarized in three fairly straightforward sentences. The Federal involvement in engineering education is generally a byproduct of 40 different activities in 11 civilian agencies, those activities having been designed with other objectives in mind.

The proposed fiscal year 1982 budget as of September 15 would increase the total cost for Federal civilian agency support for engineering education by about 16 percent over 1980 levels, mostly in the student financial assistance programs.

Third, most civilian agency funding for engineering contributes to the supply of engineering; much less relates to engineering faculty, equipment, curricula.

Federal activities that support engineering education either support broad educational objectives or agencies' specific missions. Programs that have broad objectives provide the most support.

In 1980, this consisted of 11 programs located in three different agencies providing about $193 million for engineering. The remaining civilian agency support for engineering education is provided by mission agency education programs and by R. & D. grants to academic institutions.

In terms of the kinds of support provided, we found the following: Financial assistance for engineering students; new and used instructional equipment; support for an institution's general operation; and development funding for particular departments or areas of study, curricula, and faculty.

The proposed fiscal year 1982 budget, as of September 15, 1981, and I stress that date because the 1982 budget is still in flux, would increase overall support for engineering education by 16 percent compared to 1980. This increase is due almost entirely to the 24-percent increase in the Department of Education student financial assistance programs. If these programs are excluded, total Federal support would be reduced by 33 percent because 14 of the 39 programs which we identified are slated for termination in 1982.

There are four areas of engineering which are considered by observers to be problems: current and future supply of engineers, the current and future supply of engineering faculty, obsolescence of instructional equipment, and the focus of engineering curriculums.

Because these concerns have not been precisely defined and the available data are divergent, we did not attempt a rigorous comparison of current Federal efforts with current and projected needs. Instead, we attempted to generally look at the Federal efforts that appear likely to influence these areas of concern.

We found that most civilian agency support for engineering education relates to the supply of engineers. This is nominated by the student financial assistance program. Much less of that support relates to faculty shortages, obsolete instructional equipment, and engineering curriculums.

Mr. Chairman, that summarizes the main points of my statement.

[The prepared statement of Mr. Havens follows:]

U.S. GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

FOR RELEASE ON DELIVERY
Expected at 9:30 a.m., EST
Wednesday, October 7, 1981

STATEMENT OF

HARRY S. HAVENS

ASSISTANT COMPTROLLER GENERAL

FOR PROGRAM EVALUATION

BEFORE THE

HOUSE COMMITTEE ON SCIENCE AND TECHNOLOGY

ON

"FEDERAL GOVERNMENT INVOLVEMENT

IN ENGINEERING EDUCATION"

Mr. Chairman and Members of the Committee:

We are pleased to be here to discuss GAO's work in progress on Federal involvement in engineering education. During the past few months we have worked closely with your staff on engineering education issues.

Today we will briefly address three questions:

--What is the nature and extent of Federal involvement in engineering education?

--How will proposed budget cuts affect Federal involvement?

--How does Federal involvement relate to current concerns about engineer supply, faculty shortages, obsolete instructional equipment, and curriculum focus?

SCOPE

To address these questions, we have developed a comprehensive overview of Federal civilian agency activities that help support engineering education. We included fiscal year 1980 activities and their program and budget information for fiscal years 1980, 1981, and 1982. We did not include programs that focus primarily on continuing education, technician training, post-doctoral study, women and minorities, or international student and faculty exchange. Although the Department of Defense and the Veterans Administration have relevant programs, we did not include them because of time and resource limitations.

SUMMARY OF FINDINGS

Based on our analyses to date, we can summarize our findings in three statements:

--Federal involvement in engineering education is generally a by-product of 40 different activities in 11 civilian agencies that were designed with other objectives in mind.

--The proposed fiscal year 1982 budget, as of September 15, 1981, would increase total Federal civilian agency support for engineering education by about 16 percent over 1980 levels. However, student financial assistance programs account for nearly all of this increase; other programs would be reduced by one-third.

--Most civilian agency funding for engineering contributes to the supply of engineers; much less relates to engineering faculty, equipment, and curricula.

FEDERAL INVOLVEMENT IN ENGINEERING EDUCATION

Federal activities that support engineering education can be characterized in two ways: in terms of their objectives and in terms of the kind of assistance they provide.

In terms of objectives, Federal activities either support broad educational objectives or agency-specific missions.

Programs that have broad educational objectives provide the most support. In 1980, 11 programs, located in 3 different agencies, provided more than $193 million for engineering education. Two other programs, for which exact funding information for engineering education is not available, also provided support. The General Services Administration distributed over $118 million (original acquisition value) in surplus Federal property for general education purposes. The Cooperative Education Employment program (coordinated by the Office of Personnel Management) employed over 1,600 engineering students at 8 agencies.

The remaining civilian agency support for engineering education is provided by mission agency education programs and by R&D grants to academic institutions. Eight agencies with a total of 24 programs support engineering education in particular subfields of science and engineering related to their missions (e.g., the National Aeronautics and Space Administration supports training in aeronautical engineering and mechanical engineering; the Department of Transportation supports training in mechanical, electrical, and sanitary engineering as part of its highway technology and safety programs; and the Department of the Interior supports training in mining, metallurgical,

ceramic, petroleum, geological, and environmental engineering as part of its mining and minerals programs). In 1980, these 24 programs together provided approximately $35 million for engineering education. In addition, the National Science Foundation and the Department of Energy each operate programs that distribute used scientific equipment to academic institutions. Insufficient data prevented us from determining what portion of this equipment was used for engineering instruction in 1980. Civilian agency R&D programs supported approximately 6,900 graduate engineering students in 1980 and provided an undetermined amount of instructional equipment to engineering schools. (Dollar amounts for the contributions of R&D funding to student assistance and instructional equipment are not available.)

In terms of the kind of assistance provided, we identified several different types of support: financial assistance for engineering students; new and used instructional equipment; support for an institution's general operation; and development funding for particular departments or areas of study, curricula, and faculty.

The largest source of Federal civilian agency support for engineering education is student financial assistance programs. Of the estimated 158,000 engineering students who received support from Federal civilian agencies in 1980, about 93 percent received financial aid from the Department of Education's student assistance programs. The rest of the students are supported through R&D funding (4 percent), mission agency training programs (2 percent), and the Cooperative Education Employment Program (1 percent).

Most of the instructional equipment is provided through R&D funding and through used equipment programs at the National Science Foundation (NSF), the Department of Energy, and the General Services Administration. Precise data on the total value of equipment provided through these activities are not available. In 1980, approximately $6 million was provided for new instructional equipment by the educational programs of mission agencies and NSF. About two-thirds of that amount went to the Coast Guard, Merchant Marine, and State Maritime academies.

Of the civilian agency funds for institutional support, about 77 percent are expended in the operation of the U.S. Merchant Marine and Coast Guard Academies and the State Maritime Academies. Most of the remaining funds go to land-grant colleges.

Civilian agency support for development of particular departments or areas of study, curricula, and faculty is considerably smaller than support for students, equipment, and institutions. In 1980, civilian agencies supported such development with approximately $7 million scattered across 12 programs in 7 agencies.

EFFECTS OF PROPOSED FY 1982 BUDGET

The proposed fiscal year 1982 budget, as of September 15, 1981, would increase overall Federal support for engineering education by approximately 16 percent over 1980 levels. This increase is due almost entirely to the planned 24 percent increase in the Department of Education's student financial assistance programs. These calculations do not take into account the three

used equipment programs, research and development funding, and the Cooperative Education Employment program because adequate funding information was not available. Recent proposals for additional budget cuts in all areas, particularly in the Education Department's (ED) Guaranteed Student Loan program (GSL), could significantly change this outlook.

If ED's financial assistance programs are excluded, total Federal support will be reduced by 33 percent because 14 of the 39 programs reviewed are slated for termination in 1982. Among those directed at broad educational objectives, five of the six NSF programs and both the programs providing aid to Land Grant Colleges (i.e., Bankhead-Jones and Morrill-Nelson) are to be terminated.

Agency support for engineering education in fields related to their scientific and technological missions would increase in the energy and aeronautics and space areas but would decline by about 24 percent overall due to elimination of all programs in the environmental protection, mining and minerals, and ocean engineering areas.

RELATION TO CURRENT CONCERNS

As you have heard frequently, four areas of engineering are considered to be problems: the current and future supply of engineers, the current and future supply of engineering faculty, obsolete instructional equipment, and the focus of engineering curricula. Because these concerns have not been precisely defined and available data are divergent, we did not attempt a rigorous comparison of current Federal efforts

with current and projected needs. Instead, we have attempted to generally describe the Federal efforts that appear likely to influence these areas of concern.

We have found that most civilian agency support for engineering education relates to the supply of engineers. Much less of that support relates to faculty shortages, obsolete instructional equipment, and engineering curricula.

The supply of engineers is likely to be influenced by those programs that provide financial assistance to students. An estimated 146,000 engineering students received aid in 1980 from the Department of Education's student financial assistance programs. In the same year, R&D funding and mission agency training programs provided support for approximately 10,000 students in specific subfields of engineering.

Programs that provide student support may also affect the supply of engineering faculty. However, none of these programs currently provides incentives for engineering students to take faculty positions upon graduation. Activities that stimulate the professional development of engineering faculty through workshops, institutes, or conferences may influence faculty retention. However, these programs are small, fragmented, and of such short duration that they are unlikely to have much effect.

Both new and used instructional equipment are provided to engineering schools to the extent previously described. Finally, engineering curricula are addressed by seven small programs that totaled about $2.7 million in 1980. Of these, one NSF program awarded one grant designed to influence the orientation of engineering curricula toward a more industrial focus. That program is scheduled for termination in FY 1982, along with all but one of the other six curriculum programs.

Mr. Chairman, this concludes my remarks. I would be happy to answer any questions you may have.

Mr. FUQUA. Thank you very much.

I'm a little bit concerned. You mentioned the increase of 16 percent in Federal support for engineering education—and that was coming from student financial assistance programs. I thought that was going down in the new budget figures. Am I in error?

Mr. HAVENS. I understand your point. The budget accounting for those programs gets rather complicated.

What we are referring to there is budget authority. Budget authority is not necessarily directly translated to, and in this case does not directly translate into assistance for students. Budget authority, particularly in the guaranteed student loan program, represents the costs of subsidies for those programs.

These subsidies consist of two basic components: One is the insurance component, in which the Federal Government pays for the loan if the student defaults. Second are the interest subsidies during the time that the student has interest deferral.

So that the current year costs of those programs——

Mr. FUQUA. Can be a carryover figure?

Mr. HAVENS. They are reflective of past years' activities.

Mr. FUQUA. That doesn't necessarily mean more money. So, that figure can be deceiving.

Mr. HAVENS. The numbers taken at face value are misleading.

Mr. FUQUA. The amount of money that goes into the Department of Education that you referred to, is that earmarked for engineering?

Mr. HAVENS. No, sir.

Mr. FUQUA. Someone can study liberal arts or humanities, something nonengineering or nonscience?

Mr. HAVENS. Absolutely. Indeed, most of the students receiving benefits under the student financial assistance programs do not study engineering. What we have attempted to do is attribute that part of the costs of the program to the engineering component in proportion to the number of engineers in colleges and universities.

It is an estimate at best and that is as close as we can get because the data are not that precise. We tried to attribute the cost to the engineering component as an indication of support for engineering along with a lot of other things.

Mr. FUQUA. There is nothing in that figure that you spoke of, the 16-percent increase, that affects faculty salaries, or instructional instrumentation, or improved facilities, or enhanced research facilities. None of those are included?

Mr. HAVENS. No, sir. That was one of the points we made in terms of the relationship between the Federal programs and the areas which are of concern to the engineering and science community. Most of the assistance goes to encourage and assist students of engineering and does not bear on the issue of faculty, numbers of faculty, or quality of faculty, or quality of instruction, or other things of that character.

Mr. FUQUA. I think if you set aside the student loan program, I think you would find that the role in engineering education is actually decreasing overall. Is that true?

Mr. HAVENS. That is correct. The other programs, some of which are targeted to engineers or related disciplines, are generally going down. Many of them are in fact being terminated.

Mr. FUQUA. That's the purpose of these hearings, to try to get at the fact that we are in fact decreasing and have for the last few years. As was pointed out, in the increase in the student loan program, a large portion—I don't know what percentage—of the increased figure in total dollars is actually obligations from preceding years.

Mr. HAVENS. We don't have that figure. I regret that we don't. It is almost certainly quite high.

Mr. FUQUA. Would that be a fair statement to say?

Mr. HAVENS. Yes.

Mr. FUQUA. So, as far as new money is concerned, for a new engineering graduate student to borrow money to go to school, it is declining?

Mr. HAVENS. I don't have that figure. We tried to lay hands on an estimate for the 1982 budget of the volume of new loans expected to be made in fiscal 1982. We were unable to obtain it. It is not a matter of anybody refusing to give it to us. The 1982 budget is still in a state of flux.

Mr. FUQUA. Let's do a scenario. One of the witnesses yesterday is head of an engineering department at a college. He stated he had had a 300-percent increase in students for mechanical engineering over the last 5 years. Now, that's more students going after less money.

None of the money is earmarked to engineering. You stated it can go to any bona fide student that qualifies. So, it is not earmarked for engineering. If we have an increase in the number of engineering students, which I think we have had over the years, as indicative of this one particular case—I don't know if this is typical of all engineering schools—then we have more people after less money, which I would think makes the conclusion that there is less money for student assistance per student.

Mr. HAVENS. That would imply, certainly, that a smaller proportion of the engineering students in that case were being assisted than was the case in the past.

I presume that some fairly significant number of engineering students are able to make it without assistance. So, it is difficult to say how critical that becomes in terms of the ability of students to receive their education.

Mr. FUQUA. Has there been a decrease in education programs for engineers in other departments?

Mr. HAVENS. Well, there are a number of programs scattered throughout the Government which directly or indirectly assist engineering students. Many of those programs are being terminated. Others are being reduced. So, I think in general this year as last, if one exempts the student financial assistance programs and looks only at the mission agencies, in that area from 1980 to 1981, there is a decline of about 8 percent in funding.

From 1981 to 1982, the latest figures we have available, there was a further decline of about 27 percent, leaving a total decline from 1980 to 1982 of about one-third.

Mr. FUQUA. That's a 30-percent decline?

Mr. HAVENS. Yes. Those programs are being reduced, and a number of them are being terminated.

Mr. FUQUA. The reason I'm going at this point is because when you say in your statement that it is increased by substantial amounts to 16 percent—it is really a very misleading figure. I don't want somebody to walk out and think we have this big bonanza.

Mr. HAVENS. No, sir. You are correct, and I attempted to qualify that number at a later point in my statement, to make it clear that that taken by itself is a misleading indicator.

Mr. FUQUA. Mr. Winn?

Mr. WINN. Thank you, Mr. Chairman.

Mr. Havens, I think you barely touched on it. What if the Department of Education is phased out? Who takes over some of the jurisdiction of the loans? Where would that be going? Do you know? Have you looked into that?

Mr. HAVENS. No. The best of my understanding is the decision on what happens to those programs if the Department of Education is terminated has not yet been decided. I presume some of those programs would be chosen to continue in another agency, but I don't think the other agency to take over those programs has been chosen. Health and Human Services would be an obvious candidate.

But, I don't know that they have chosen one. Someone certainly would have to continue to administer the outstanding loans and continue to collect amounts due under those outstanding loans.

Mr. WINN. I'm sure that Health and Human Services would probably get the jurisdiction in the sense that it had most of it before. But, I don't think there is much doubt, in my mind, anyway, that both DOE's are going out sometime during the Reagan administration. I just wondered if your agency had looked into that possibility or made any suggestions of where the funding should go, who should be in charge of the collections.

Mr. HAVENS. To the best of my knowledge, we have not made recommendations and have not looked in detail at that. I would presume that before looking at it in much depth, we would be wanting to look at what the administration was proposing to do. Where the programs should go depends, I think, in large part on which programs are retained and which programs are actually terminated, with the exception of the Department, if that should occur.

Mr. WINN. What role has OMB played in affecting the support of the various mission agency programs for engineering manpower training such as in NASA, DOD, or DOE? Are they supportive of these programs? Do they play a part at all?

Mr. HAVENS. Well, I would have to say that we do not know how the decisions were made in detail as to which programs were reduced and terminated and which were not.

Mr. WINN. The various agencies that I mentioned send their budgets to OMB and OMB then makes a decision based on whatever their many reasons might be. But, I wondered in your experiences, have you gotten any feeling of support from OMB or is it hard and cold figures down there?

Mr. HAVENS. I guess my overall impression is—and perhaps one of the other staff has talked to OMB staff—I don't know. My overall impression would be that looking at the budget as a whole, support for this sort of activity has been generally accorded lower

priority at OMB than I think we have seen in the past periods. The reasons for that, I don't know.

It is also possible, I would have to add, that OMB has given agencies greater discretion in where they take their cuts, has told them that they must take cuts, and has left it to the agencies to decide where to take them. In that sort of a circumstance, agencies, as a matter of general practice, tend to take their cuts in places that have the least immediate effect, even though they may have severe long-term effects.

So that an agency, if asked to take an x million dollar reduction in its budget, for example, may well reduce extensively its internal training program which, in some cases, would affect engineering.

Mr. WINN. Other than the cuts which OMB is recommending, you don't get the feeling that it is antitraining programs? They leave the decisions up to the agencies after they say you have to cut back 10 percent or 12 percent?

Mr. HAVENS. Barring evidence to the contrary, that would be my impression.

Mr. WINN. Thank you very much. Thank you, Mr. Chairman.

Mr. FUQUA. Mr. Dunn?

Mr. DUNN. Thank you, Mr. Chairman.

You were talking about the changes made in the guaranteed student loan program. Isn't it possible that with the changes implemented by OMB, that indeed, we will have not fewer students involved in the guaranteed student loan program, but more that truly need it? One of the changes is that in the past, your old man could make $250,000 a year and you could qualify. You can no longer do that.

I have some grave reservations whether that student really needed that assistance. Now, we are going to have money targeted to the students that really need it. One of the possibilities is that we will have more students involved. Do you agree?

Mr. HAVENS. Well, certainly, one of the possibilities is that those who receive the assistance will be more demonstrably in need of it. Whether that will affect the number of students receiving assistance or whether it will simply reallocate what is already out there in the way of assistance, whether it will affect the number of students who are actually able to attend engineering school significantly, I don't think we have a basis for judging at this point.

I think only experience will tell us what the net results of those changes are.

Mr. DUNN. The second thing. As an accountant, I would like to run an idea by you that I ran by the educators yesterday. One of the big problems is attracting students at the graduate level and keeping them there because of the salaries that they can get from industry. I believe I have a solution, and that solution revolves around the subsidies that are now given by our State universities to foreign students.

It amounts to almost $2,000 a year. Our State taxpayers are paying that subsidy. Why not up the amount of money that we charge foreign students? In my own university, Michigan State, that amounts to about $2,000 a year and entails about 200 students. If you follow the math out in that, you come up with $400,000 extra money to Michigan State.

Use that money to pay graduate fellowships. It is not a cost to the Government. It is not a cost to the State. We all benefit. There are no losers in that scenario, either. In talking to several different universities, they agree unanimously that if we up the tuition to foreign students $2,000, it would not stop them from coming to our universities, simply because of the costs already associated in getting to this country, No. 1, and because of the level of education we offer.

What's wrong with that?

Mr. HAVENS. I guess I would have to think it through in somewhat greater detail before I gave any sort of a firm response. I think there probably would be some reduction in the number of foreign students that come to this country under those circumstances because I suspect cost is a consideration to at least some of them. Whether that is good or bad——

Mr. DUNN. The airplane flight over here and back from India or France is more than $2,000. It is not going to affect whether they stay for a year or not. They are being subsidized by their government. We have had a parade of witnesses and no one has offered a concrete solution. I believe that is a concrete solution that does involve the tax—doesn't cost the taxpayers of this country.

Mr. HAVENS. I'm not sure of the engineering facilities, but at least in some disciplines, foreign students that come to this country then remain and work in this country. So that if there were any effect of discouraging foreign students here, it might also affect our supply of engineers after graduation.

Mr. DUNN. Some of them, the administrators of these programs, tell me about 60 or 70 percent of these students go back to their own countries. We are subsidizing brainpower that will go back and compete with us. It makes no sense.

Mr. HAVENS. We will be happy to look at it and supply you any further thoughts we may have.

Mr. DUNN. Thank you.

Mr. FUQUA. I have one final question along the same lines of our colleague, Mr. Winn, regarding OMB. It is my understanding that OMB beginning 10 years ago, started singling out fellowship programs and student assistance programs for the budget knife rather than giving that option to the agency. Is that correct?

Mr. HAVENS. Well, I may have misunderstood Mr. Winn's question. I assumed he was referring primarily to mission agencies and fairly small programs.

Mr. FUQUA. That's what I was thinking of, mission agencies. I think of EPA, NASA, and some of the others, that after the Sputnik increase that we had, we followed for about 10 years. Then, the last 10 years, we have had this decline. Many of them, I understand, have been ordered by OMB.

Mr. HAVENS. That is quite possible. I really can't confirm or deny that. It was—at the time I was in OMB in the late 1960's and early 1970's——

Mr. FUQUA. Maybe it happened while you were there. [Laughter.]

Mr. HAVENS. There were perhaps some indications of it. We had some experience at that time. Again, during both the Johnson administration and the Nixon administration we had some concerns about the proliferation of fairly small programs, each of

which in and of itself did not seem to be sufficient to address a significant problem.

At that point, the policy direction that we took was generally to favor broad-based programs to support education in general, what are now the student financial assistance programs, in lieu of very small, highly targeted programs that may or may not in fact lead to solving whatever problem they were addressed at.

That was the philosophy then. It may well still be the same philosophy. It is certainly consistent with events as they have occurred. But, another theory consistent with that set of events with respect to the fairly small programs in the mission agencies would be that when squeezed, this is where the agencies choose to take the cut.

I really don't think we have hard evidence one way or the other. The facts are consistent with both theories. There may well be both theories actually at work and bearing on the question.

Mr. FUQUA. Thank you very much. We appreciate your being here with us this morning and sharing your thoughts on this very important issue.

There is a rollcall vote going on. The committee is going to stand in recess for 5 or 7 minutes. We will be right back.

[Voting recess.]

Mr. FUQUA. The committee will resume.

Our next panel of witnesses will be Dr. Frank Press, the President of the National Academy of Sciences and Dr. Courtland Perkins, President of the National Academy of Engineering.

[The biographical sketches of Dr. Press and Dr. Perkins follow:]

July 1981

FRANK PRESS

Frank Press was born in Brooklyn, New York in 1924. He received his undergraduate degree in physics from the City College of New York, and advanced degrees in geophysics from Columbia University in 1946 and 1949, when he joined the Columbia faculty, becoming associate professor in 1952, working in the areas of geophysics and oceanography. In 1955 Dr. Press was appointed professor of geophysics at the California Institute of Technology, and two years later became director of its Seismological Laboratory. He was named in 1965 as the head of the then Department of Geology and Geophysics at the Massachusetts Institute of Technology (MIT), which, under his leadership, expanded into planetary sciences, oceanography, interdisciplinary studies, and the joint program with the Woods Hole Oceanographic Institution, and was renamed the Department of Earth and Planetary Sciences. In 1977 he was appointed by President Carter as the President's Science Advisor and Director of the Office of Science and Technology Policy. In January, 1981, he returned to MIT where he was appointed Institute Professor, a title MIT reserves for scholars of special distinction. Dr. Press has been elected as the 19th President of the National Academy of Sciences (NAS), where he will assume his new office on July 1, 1981.

Dr. Press is recognized internationally for his pioneering contributions in geophysics, oceanography, lunar and planetary sciences, and natural resource exploration, but his primary scientific activities have been in seismology and the study of the earth's deep interior. Recognizing the importance of long-period surface waves in studying the earth's structure, he developed the theory for these waves and the instrumentation to record them. Today the analyses of seismic surface waves and free oscillations are among the most powerful techniques for studying the structure and properties of the earth's crust and deep interior. Dr. Press also saw the need to develop techniques for geophysical studies of the moon and planets, using landed observatories. Author of 160 scientific papers, he is also the co-author of the textbook Earth, widely used in courses in both American and foreign universities.

Dr. Press has been a leader in major national and international projects. He helped organize and gave impetus to the International Geophysical Year, the first coordinated worldwide attempt to measure and map various geophysical phenomena, a decade-long effort that involved international explorations of Antarctica and the oceans. Mt. Press in Antarctica is named for him. Dr. Press provided leadership in research efforts on earthquake prediction in the United States, and in international cooperation with Japan, the USSR, and the People's Republic of China.

As NAS president, Dr. Press will continue a long career of public service, in addition to his distinguished scientific work. He served on the President's Science Advisory Committee during the Kennedy Administration and on the Baker and Ramo Presidential Advisory Committee during the Ford Administration. He was appointed by President Nixon to the National Science Board, which is the policy-making body of the National Science Foundation, and he also served on the Lunar and Planetary Missions Board of the National Aeronautics and Space Administration. Dr. Press participated in the bilateral science agreement negotiations with the Soviet Union, and was a member of the U.S. delegation to the nuclear test ban negotiations in Geneva and Moscow.

Major initiatives of his Washington service as OSTP Director and Science Advisor during the Carter Administration included increasing the Federal commitment to the support of basic research; the introduction of new measures to spur industrial innovation; joint research ventures involving industry, the university, and the government; and regulatory reform, particularly in improving the scientific basis of proposed regulations. Dr. Press was largely responsible for the U.S. - China scientific cooperation agreements in 1979.

Dr. Press is a member of several professional organizations, and is a former president of both the Seismological Society of America and the American Geophysical Union. He was elected to the National Academy of Sciences in 1958, the American Academy of Arts and Sciences in 1966, and the American Philosophical Society. In 1981 he was elected as a foreign member of the French Academy of Sciences. He is the recipient of numerous honors, among which are the Gold Medal of the Royal Astronomical Society, the Arthur L. Day Medal of the Geological Society, and the Bowie Medal of the American Geophysical Union. He was awarded the Department of the Interior's Public Service Award in 1971 and NASA's Distinguished Public Service Medal in 1973. Dr. Press has received 11 honorary doctoral degrees. His unique distinction lies perhaps in the dual contribution of the impact of his scientific work on the development of modern geophysics and the influence of his personal leadership in national science planning and administration.

Dr. Press is married to the former Billie Kallick of St. Louis. The Presses have two children and one grandchild.

COURTLAND D. PERKINS

Professor Perkins was born in Philadelphia, Pennsylvania on December 27, 1912. He was graduated from Swarthmore College in 1935 and received his M.S. Degree from the Massachusetts Institute of Technology in 1941. He has received D.Eng.(H) Degrees from Lehigh University, Rensselaer Polytechnic Institute and Swarthmore College. During World War II he headed the Stability and Control Unit of the Aircraft Laboratory, U.S. Army Air Corps, at Wright Field. He was active during this period improving the sophistication of flight test and flight research operations within the Armed Forces, and had a hand in the creation of the first Air Force Test Pilot School now active at Edwards Air Force Base, California. Immediately following the war, Professor Perkins and a Wright Field colleague published a fundamental book entitled Airplane Performance, Stability and Control.

After leaving Wright Field in 1945, Perkins joined the Princeton faculty where he has held the rank of Professor since 1947. He was appointed Chairman of the Aeronautical Engineering Department in 1951, and twelve years later was appointed Chairman of the newly formed Department of Aerospace and Mechanical Sciences. In the fall of 1974 he was named Associate Dean of the School of Engineering and Applied Science.

During his tenure at Princeton, Professor Perkins twice took leave of absence to serve the Department of Defense. In 1956-57 he served as Chief Scientist of the USAF, and in 1960-61 was Assistant Secretary of the USAF for Research and Development. He has served on the USAF Scientific Advisory Board since 1946; he served as Chairman of the Board from 1969 to 1972 and also from 1977 to 1978. He also serves as Senior Scientist of the USAF-SAB.

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In 1963 he was elected Chairman of the Advisory Group for Aeronautical Research and Development (NATO), and served in this capacity until 1967. He served as a member of the Space Science Board of the National Academy of Sciences from 1964-70, and as a member of the Defense Science Board from 1969 to 1973 and from 1977 to 1978. He has been a member of NASA's Space Program Advisory Committee and Chairman of its Space Systems Committee from 1972 to 1977. He was President of the American Institute of Aeronautics and Astronautics in 1964. He has served on the Board of Directors of Fairchild Industries Corporation, American Airlines, Inc., The MITRE Corporation, The Keuffel & Esser Company, and the C. S. Draper Laboratories.

In April of 1975 Perkins was elected to the Presidency of the National Academy of Engineering, succeeding Dr. Robert C. Seamans, Jr., and re-elected in 1978 to serve a four-year term.

Professor Perkins is an Honorary Fellow of the American Institute of Aeronautics and Astronautics, a Fellow of the Royal Aeronautical Society, a Member of the International Academy of Astronautics (Paris), a Corresponding Member of the National Academy of Engineering of Mexico, and a member of the American Helicopter Society, Sigma Xi, and Tau Beta Pi. He was elected to the National Academy of Engineering in 1969 and to the American Academy of Arts and Sciences in 1977. He has been made a member of the French Legion d'Honneur. He is married, has two children, and resides in Alexandria, Virginia. He is a member of the Princeton Club of New York, the Quissett Yacht Club, the New York Yacht Club, and the Cosmos Club of Washington, D.C.

May 1981

STATEMENTS OF DR. FRANK PRESS, PRESIDENT, NATIONAL ACADEMY OF SCIENCES AND DR. COURTLAND PERKINS, PRESIDENT, NATIONAL ACADEMY OF ENGINEERING

Mr. FUQUA. Frank, we are happy to welcome you back once again. Is this the first time you have testified as the President of the Academy?

Dr. PRESS. That's right.

Mr. FUQUA. Well, let me welcome you in that capacity. You have been here many times in the past as science adviser to the President. We are happy to have you in your new position of responsibility, and look forward to continuing our relationship that we have had. It has been a very warm one over the years.

We will be happy to hear from you.

Dr. PRESS. Thank you, Mr. Chairman.

With your permission, I would like to reduce the extent of my remarks and submit the full text for the record.

Mr. FUQUA. Without objection.

You may summarize. The same with Dr. Perkins.

Dr. PRESS. Mr. Chairman, members of the committee, I appreciate the opportunity to be with you here today to join in this discussion of engineering manpower concerns.

Dr. Perkins and I have coordinated our testimony, and I will address the issue in the broader context of some of the challenges the Nation faces in the years ahead. He will address the more specific concerns of engineering education that have emerged from a series of discussions that the National Academy of Engineering has had over the years.

Mr. Chairman, I believe your hearing should seek to provide a clear and factual exposition upon which decisions can be formulated in meeting engineering manpower needs for the next decade and define the appropriate roles to be played by all concerned in sharing that responsibility.

We must provide modern teaching and research facilities and other programs to insure that talented individuals in adequate numbers are available for service in our vast scientific and technological enterprise.

While our Nation is still the technological leader of the world, certain worrisome signs should lead us to examine carefully whether these goals are being well served. There is a widespread belief that our technology today is growing less competitive with other industrial nations, and that the scientific and engineering facilities in which we educate and train future generations show an alarming slippage in comparative quality.

The sufficiency and quality of engineering manpower resources for the future are directly related to the overall quality and level or research programs in our academic community. Only if our universities remain at the cutting edge in frontier research endeavors can we advance the state-of-the-art and improve the training of our youth.

Other countries may turn out more engineers than we do. We should not be deceived by that statistic. It is the quality of education that counts and it is the involvement of our engineering faculties in the forefront of research and development, and in the

dissemination of the most current understanding of the state-of-the-art to students through the educational process.

Today, our university departments of science and engineering in many instances utilize outmoded equipment, equipment that often lags behind the technological facilities provided in the laboratories of our industrial plants. In many cases, our students are not well-prepared for their first jobs because of this.

Industry has increasingly recognized the value for its own future needs of plant modernization at univerisities. But, however encouraging it is to see the growing contribution of industry to solving these problems, it cannot be expected to shoulder the entire burden alone.

The issue of obsolescence must be faced jointly by the Government, by industry, by the universities. One useful Government initiative has been the incentive created for industrial support by the recently enacted Reagan administration tax program which extends tax benefits to companies donating certain kinds of equipment to universities for research.

If this provision is liberally used, there can be a significant contribution toward improving the situation.

While Dr. Perkins will talk to you in detail about emerging engineering manpower demands, I would like to call attention briefly to a particular aspect of engineering manpower demand that, in my view, we cannot ignore. The decade ahead will witness a second industrial revolution growing out of developments in high technology. To survive, many middle level and smaller industries will increasingly require the services of competent and highly skilled engineers. These prospective manpower demands have never been adequately factored into projections of future needs for engineers.

I believe that the Government has a responsibility to monitor the supply and demand of scientific and technical personnel both in terms of quantity and quality and to supplement the free market role when it is in the national interest.

This is an area in which the Government as representative of the public interest must be watchful. For example, we observed that the supply of engineers is beginning to catch up with demand. Some studies show that by the end of the decade, supply and demand should be in balance except perhaps in a few specialties.

I would like to add that not everybody agrees with this projection. There is a great deal of uncertainty about future demand for engineers. If this high-technology industrial revolution does accelerate, I think the demand might have been underestimated.

But, there are near-term and intermediate-term needs about which everyone agrees and there are gaps and questions of quality. As I said earlier, the latest state-of-the-art equipment to train these engineers is lacking. Further, the burgeoning numbers of engineering students have overcrowded the classroom at a time when there is a shortage of qualified teachers.

It is questionable that graduating engineers are receiving quality education in the faster growing disciplines such as computer engineering, robotics, electronics, genetic engineering, and the several fields of energy engineering. And, whether our universities can

keep apace of the accelerating advances of modern technology in these new fields is another vexing question.

Without both, private and Government support, and without institutional changes within universities, the gap may widen further in the years ahead.

I'm concerned that support will lag and that industry and private sources cannot make up the difference, especially in the areas of instrumentation, and in the provision of incentives for junior faculty to remain at our universities. These are short-term and I hope manageable problems if we can define a national policy of cooperative support by both Government and industry.

But, there are longer term conditions that could limit our ability to stay in the forefront of the world's technological leaders. I hope, Mr. Chairman, that your committee will address this in your future deliberations. It has to do with the quality of science and mathematics education in our primary and secondary schools.

Last year, my predecessor, Dr. Handler, called your attention to a report of the National Research Council entitled "The State of School Science." It is a review that was supported by the National Science Foundation concerning the quality of teaching of mathematics, science, and social studies in American schools.

The survey data, firsthand observations, and other information from this and additional studies described a troubled American school system. Student performances show striking decline. Teacher qualifications and effectiveness in the classroom has dropped. Use of laboratory instruction and the inquiry approach seems to be diminishing. A heavy emphasis, systemwide, on multiple-choice testing has elevated simpler and less meaningful instructional objectives and reduced the importance of learning concepts and relationships.

The educational environment in our schools is not good. All of this cannot help but affect our future ability to maintain a leadership position in technology in the world.

An impending crisis awaits us as these ill-prepared secondary students begin to move into society, into vocational jobs, or into education. I should also like to underscore a problem by reference to the findings of a comparative study prepared by the National Science Foundation and the Department of Education just last year.

The major thrust of that survey is that in each country studied—Japan, Germany, and the Soviet Union—in each of these countries, there is a strong national commitment to quality science and mathematics instruction as an essential part of the precollege work. The result is a work force which, at all levels, has a relatively high degree of science and mathematics skills, and this has been a factor in the very rapid expansion of their technical industries.

In a nutshell, the university needs are significant. The traditional sources of support—endowment income, gifts, support by State legislatures—will be insufficient to solve some of these problems. Industry is increasing its support. But industrial leaders themselves say that they cannot fill the gap.

Who will pick up the difference? I think this is where we need a significant statement about Government policy. I do hope, Mr. Chairman, that as a result of your hearings, we might begin the

process of establishing a national consensus on these very important questions.

I will be pleased to respond to the committee's questions, Mr. Chairman, but perhaps first you may wish to have Dr. Perkins present his statement. We then can jointly participate in the discussion.

[The prepared statement of Dr. Press follows:]

STATEMENT

by

Frank Press
President
National Academy of Sciences

Mr. Chairman and Members of the Committee. I appreciate the opportunity you have provided to us at the National Academies of Sciences and Engineering, to join in your discussion of "Engineering Manpower Concerns." It is gratifying that at this, my first appearance before your Committee as President of the National Academy of Sciences, I will be privileged to discuss a subject that has been a serious concern of mine both as a scientist, as an educator, and as an individual involved in the formation of science policy at the national level. Dr. Courtland D. Perkins, the distinguished President of the National Academy of Engineering, joins me as a member of this panel and he and I both are pleased to provide whatever assistance we can in addressing the questions you have posed.

With your indulgence, I would like to address these concerns in the broader context of challenges the nation faces in science and technology during the coming decades, drawing in part upon my experience of the past five years during which the demands of scientific and engineering manpower for serving modern technology were

an acute and continuing problem. My colleague, Dr. Perkins, will address more specifically the concerns of engineering education that have emerged from the series of discussions and panel deliberations held by the National Academy of Engineering over the past several years. I should like to commend his leadership in bringing together members of that Academy to evaluate the state of engineering education and the availability and distribution of engineering manpower. These activities exemplify the useful role that can be fulfilled by the Academies in advising the government on timely issues of concern to the nation.

Mr. Chairman, your hearings should seek to provide a clear and factual exposition upon which decisions can be formulated in meeting engineering manpower needs for the next decade and defining the roles to be played by government, industry and the academic community in sharing this responsibility. Utilizing these institutions, we must provide modern teaching and research facilities and other programs to assure that talented individuals in adequate numbers are available for service in our vast scientific and technological enterprise. While our nation is still the

technological leader of the world, certain worrisome signs should lead us to examine carefully whether these goals are being well served. There is a widespread belief that our technology today is growing less competitive with other industrial nations and that the scientific and engineering facilities in which we educate and train future generations show an alarming slippage in comparative quality.

The sufficiency and quality of engineering manpower resources for the future are directly related to the overall quality and level of research programs in our academic community. Only if our universities remain on the cutting edge and frontier of research endeavors, can we both advance the state of the art and improve the training of our youth. Thus, the problems we face are not just those of responding to manpower demands.

Today, our university departments of science and engineering in many instances utilize outmoded equipment--equipment that often lags behind the technological facilities employed in the laboratories of our industrial plants. The problem has existed for a decade, but only recently have we been able to enlist the government as an active partner in a cooperative

effort to replace inadequate and obsolete equipment. Yet today's stringent budget constraints have, for all practical purposes, aborted this effort.

Industry has increasingly recognized the value, for its own future needs, of plant modernization at universities. But, however encouraging it is to see the growing contributions of industry to solving these problems, it cannot be expected to shoulder the entire burden alone. Obsolescence of equipment in our universities must be addressed, and quickly, by developing additional financial support from the Federal Government, industry, and other private sources.

One useful government initiative has been the incentive created for increased industrial support by the recently enacted Reagan Administration tax program which extends tax benefits to companies donating certain kinds of equipment to universities for research. A liberal use of this provision by industry could make significant contributions toward modernizing obsolete academic laboratories. More such innovative approaches must be effectuated.

While Dr. Perkins will talk to you in detail about emerging engineering manpower demands, I would like to call attention briefly to a particular aspect of engineering manpower demand that, in my view, we cannot ignore. The decade ahead will witness a second industrial revolution growing out of developments in high technology. To survive, many mid-level and smaller industries will increasingly require the services of competent and highly skilled engineers. These prospective manpower demands have never been adequately factored into projections of future need for engineers.

I believe that the government has a responsibility to monitor the supply and demand of scientific and technical personnel, both in terms of quantity and quality, and to supplement the free market role when it is in the national interest. Dr. H. Guyford Stever, Chairman of the Academy's Assembly of Engineering, in testimony before your Committee earlier this year, pointed out this need when he stated that, "The match between some of the educational product, that is, the graduates of the universities, and the needs of industry -- now the largest employer of all of these engineers and scientists -- is not good." This is an

area in which the government, as representative of the public interest, must be watchful. For example, we now observe that the supply of engineers is beginning to catch up with demand, and some studies show that by the end of the decade, supply and demand should be in balance, except perhaps in a few specialties. However, this does not address the question of near and intermediate term needs, of gaps, nor of quality. As I said earlier, state of the art equipment to train these engineers is lacking. Further, the burgeoning numbers of engineering students on our campuses have overcrowded the classroom at a time of a shortage of qualified teachers. It is questionable if graduating engineers are receiving quality education in the faster growing disciplines such as computer engineering, robotics, electronics, genetic engineering, and the several fields of energy engineering. Whether our universities can keep apace of the accelerating advances of modern technology in these new fields is another vexing question. Without strong external support from government and industry, innovative campus research and instruction will fall seriously behind, further widening the gap in quality between academic training and

industrial needs. In my view, the government is lagging in its support as witnessed by the severe selective reductions in certain areas of the budget, especially funds for instrumentation and scientific education. This is to be regretted for it could impede the Administration's goal of building the nation's industrial strength.

These are short-term and, I think, manageable problems, but there are other longer-term conditions that could limit our ability to stay in the forefront as the world's technological leader. These, Mr. Chairman, are the ones which you and your Committee may find appropriate to address in your further deliberations.

Last spring my predecessor, Dr. Philip Handler, called your attention to a report of the National Research Council entitled "The State of School Science." It is a review supported by the National Science Foundation of the teaching of mathematics, science and social studies in American schools. The survey data, first-hand observations, and other evidence from this and additional studies commissioned by the National Science Foundation, describe a troubled American school system. Student performance shows a striking decline.

Teacher qualifications and effectiveness in the classroom have dropped. The use of laboratory instruction and the inquiry approach seem to be diminishing. A heavy emphasis, system-wide, on multiple-choice testing has elevated simpler and less meaningful instructional objectives and reduced the importance attached to the learning of concepts and relationships. Even more alarming is the educational environment of our schools. The nature of this condition is so discouraging that, for your benefit, I should like to quote directly several paragraphs of the report, "The State of School Science," to underscore these circumstances.

> "Science and the development of critical thinking skills in social studies and mathematics have assumed a low priority in the thinking of school administrators. An increased emphasis on the 'basic' learning skills, such as reading, arithmetic, and spelling, is preempting time previously available for the study of science, social studies, and mathematical concepts, especially in elementary schools. The NSF case studies observers found that in most schools natural sciences, mathematics other than

basic arithmetic, and social science inquiry were seen as having a rather limited value for the student body at large, and that providing a strong pre-college education program in science for those students who will become the nation's future scientists was not a high priority in most school systems.

The NSF case studies observers also found much apathy among students. In some schools, a lack of academic motivation was revealed by low attendance rates and the refusal of many students to attend school on a regular basis. Other students displayed their apathy towards school through passive non-involvement in classroom activities. After budget problems, the problem most frequently cited by public school teachers was student apathy, lack of motivation, and absenteeism.

The NSF case studies described many of the schools as not being intellectually stimulating places in which to work. Few principals have a good academic background in science or mathematics; this makes it difficult for them to help teachers to develop effective science and mathematics instructional programs. School

> administrators have increasingly had to become managers and interpreters of the school bureaucracy, rather than educational leaders. School system superintendents, primarily preoccupied with the details of institutional management, are not acting as educational spokesmen, but instead are responding primarily to perceived community and governmental pressures."

This is the atmosphere in which we expect our young people to learn.

It seems clear to me that today's shorter-term concerns regarding engineering manpower are only one part of a national problem. An impending crisis awaits us in the next decade as these ill-prepared secondary school students begin to move into society or to the level of college education. I thus commend this report for your careful reading.

I also should like to underscore our problem by reference to the findings of a comparative study of international science and engineering education, prepared by the National Science Foundation and the Department of Education just last year. The major thrust of that survey is that in each country studied--

Japan, Germany and the Soviet Union--"there is a strong national commitment to quality science and mathematics instruction as an essential part of the pre-college educational process. The result is a work force which, at all levels, has a relatively high degree of science and mathematics skills, and this has been a factor in the very rapid expansion of technical industries."

Although Japan's base population is roughly one-half of ours, the National Science Foundation reports that in recent years the number of degrees granted in Japan to engineers has surpassed the number granted in the United States. In Japan, 20 percent of all baccalaureate and about 40 percent of all master's degrees are awarded to engineers, compared with a figure of about five percent at each degree level in the U.S.

This same report shows an overall picture in Germany of a very high level of science and mathematics achievement among high school and college graduates. It appears that while our excellence in basic research is secure, our ability to apply technology to industrial pursuit may be inhibited by the "relatively low level of scientific and mathematical competence of our nonscientists and, in some respects, by the apparent cooling of science interest among our students generally."

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Let me suggest another thought for your consideration. Students from professional families may not suffer as much from deficiencies in our educational system. Those families, one way or another, will try to make up for the shortcomings of our public education system. Those who will suffer, however, are talented youngsters from economically deprived circumstances, or without such fortunate family backgrounds, who must rely heavily upon the schools to provide the motivation and training that will enable them to maximize their abilities. In ignoring this situation, we may be tacitly acquiescing to a class structured system, inconsistent with our national objectives of providing equal opportunity for all. We must not waste precious human resources by failing to provide an educational system marked by a high degree of excellence.

Mr. Chairman, today the university is still our institutional framework for conducting research and training our scientists and engineers of tomorrow. If the university is to continue as the basic source of our intellectual and technical talent, and I see no other alternative, we may need a new compact of understanding between government and academia that will reduce the

tensions and mitigate the adversarial relationship of the past decade. We must think carefully about the role our universities play and whether they can operate under the burden of regulations government has placed upon them at a time of financial stress. We must also provide the necessary motivation to assure that a substantial fraction of our most talented students remain within the educational system to train the talent pool required to sustain our technological and scientific leadership. In fact, it may be necessary to develop an innovative dual system within the university framework which includes research centers that will retain talented scientists and engineers.

Before I leave you, I would like you to know that the National Research Council has established a high-level Committee to investigate problems of government-university relationships in support of research. It will build upon recent studies in this field and seek approaches to resolving conflicts for the purpose of restoring mutual understanding and promoting lasting accord.

I do hope, Mr. Chairman, that this carefully thought-out study will provide a timely opportunity to view the long-range future of engineering and technological innovation and find the means of their better employment in support of our economic and social well-being.

I will be pleased to respond to questions that you may have but I respectfully suggest that you may first wish to receive Dr. Perkins' testimony and let us both respond after he has completed his statement.

Mr. FUQUA. Thank you very much, Dr. Press.

I think, because of the nature of the testimony, it would be better to hear from both of you and then have questions. We would be happy to hear from you, Dr. Perkins. Welcome to our committee.

Dr. PERKINS. Thank you. I am glad to see Mr. Brown here, too.

It is certainly a privilege to be here and to discuss this important subject with you. I am sure there is very little on this subject that you have not heard before, but I am happy to summarize some of the concerns as I see them.

Mr. FUQUA. Your full statement will be made a part of the record.

Dr. PERKINS. As Dr. Press said, we have coordinated some of these remarks so that we wouldn't be saying we don't believe what the other one just said. [Laughter.]

But, let me start out then by saying that, in my opinion, there is little question that we are facing shortages in engineering manpower, particularly in specific fields such as electronics, computer science, chemical and petroleum engineering, energy and environmental engineering and bio or genetic engineering.

That this is unquestionably so can be verified due to the very large salaries being offered by industry trying to fill shortages on a tight schedule. The big question in most of our minds is: Is this shortage in a cyclical phase which will correct itself in a short time, or are we facing a long-term trend that, if uncorrected, will have serious impact on our economic well-being and the continued viability of our national defense?

My feeling is that we are in the midst of a broad expansion of national requirements for engineering and technical manpower, and the shortages will become more serious in the next few years. We therefore must not just ignore the problem and hope it will go away. We must take active steps to solve and reduce the problems at once.

Our national shortage of engineering manpower can be reduced in several ways, but the major source of new supply comes from

the output of engineering and science programs of our universities. It is, therefore, important to examine problems in these educational programs in looking for relief.

The situation today, as you have heard, I'm sure, from other testimony, has many dilemmas. First of all, we have had a steady expansion of our undergraduate enrollments over the past 5 years. Not only are we better off in numbers, but we are better off in quality as well. This large expansion of numbers comes from several motivations. Certainly, there are the exciting new technical fields and exciting career prospects.

Second, the very high pay now being offered by industry has not gone unnoticed by our bright, ambitious young people. An engineering education is now considered as an excellent background for graduate study in the major professional fields such as business, law, and medicine. We have the undergraduates. Now what's the problem?

The problems seem to focus on the graduate education and research programs of our universities. As our undergraduates turn more to industry after receiving their BS degrees, the graduate enrollment is falling off seriously. Graduate student complements are being filled by foreign student applicants who may well return to their home country on graduation.

The falloff in engineering Ph. D.'s is having a serious impact on the staffing of our engineering schools needed to teach our large undergraduate classes. A young person who really wants to have a career in the university finds himself heavily overloaded, working with worn out research facilities, and poorly paid relative to his counterparts who have gone directly into industry.

This dilemma is serious because almost all modern universities make a Ph. D. or Sc. D. an absolute requirement for assignment to a teaching position. One could argue that if all of our top engineering BS students went directly to industry where their continuing education would be handled better with exciting problems and superb facilities, there would be no need for the university graduate programs except for the Ph. D. requirement for faculty.

If this were removed and equivalent industrial experience allowed, we could fold up graduate engineering education in the universities altogether.

Now, I certainly do not recommend this, as the university environment is an excellent one for teaching and research, and if our graduate programs have shortcomings today, we ought to fix them. Industry should not have to do its own education and should count heavily on the graduate university programs.

Many of our most brilliant new inventions and innovations have sprung from the university environment and we should value this work. Some of the reasons it is not working very well today are the result of a gradual separation of university and industrial research objectives since World War II.

The universities' research programs, almost fully funded by Government, have drifted farther and farther to the scientific end of the technical spectrum. The new Ph. D.'s supported by these programs become the new young faculty, with less and less knowledge of the real interests of industry.

Most of us recognize the problem and are trying to reestablish industry-university research programs to turn this trend around. A great deal of effort is now in progress and most certainly will be expanded in the next few years.

The interconnection between modern high-technology industry and graduate engineering at our universities must be accomplished with sophistication. If it is to be successful, a real quid pro quo must be established satisfying the interests of both parties. This can be done and has been done in the past, but we seem to have lost our touch in many cases. This must not be merely an industrial handout, but a significant working relationship of mutual interest.

The solution to our engineering manpower shortage will require us to maintain large enrollments in our engineering undergraduate programs and make them more available to our various shortages. This will require an emphasis on the advantages of an engineering career, and the proper teaching and motivation of the young students. This will require an adequate supply of well motivated and well satisfied teachers who find a career in our universities rewarding and eminently worthwhile.

Again, I believe that this can be accomplished best by the integration of industrial interests with those of the university in order that good teaching and good research can be accomplished in the face of various shortages.

It was alluded to briefly by Dr. Press that the National Research Council has been erecting a major study focusing on the problems of engineering education and research. This study will deal with the whole spectrum of concerns mentioned at these hearings.

This study is being undertaken under the auspices of the NRC and has been supported for nearly a year at phase I. The results of this have now been—have now come forth and we are establishing phase II which is being financed by many other agencies of the Government.

Many of these problems are of immediate concern and, as a consequence, progress reports from this study will be provided at regular intervals. Your committee will, of course, be provided with these as they become available.

Another aspect of the engineering manpower shortage is at the secondary or technician area. These are the young men and women who will become machine tool operators, engine mechanics, and so on. These are in short supply and are essential to both industry and the military.

A major source for these technicians comes from our rapidly expanding community colleges or trade schools. Some of the most interesting activities are being undertaken today at these levels. An example is the Community College of the Air Force. This program involves enlisted personnel in first-class technical programs using the magnificant facilities available at most operating bases. The supply of first-class technician support is crucial to both industry and to the military.

Now, I summarized what I think ought to be done about all this. I am sure you have had commentary on this. I think the universities should search out effective working relationships with modern high technology industry, insuring that a real quid pro quo be

established. Motivate the faculties to take better advantage of industrial staff as adjunct professors.

As an aside, in the past, the normal faculty of a university looks with some concern at adjunct professors and dissuades most of these appointments. I think this will have to be turned around.

Require, in most cases, real industrial experience for engineering school faculty appointments. I do not recommend as yet that we do away with the Ph. D. requirement, but I am very much tempted to do that. Equivalent industrial experience might be more important in some cases.

Do more to encourage consulting arrangements between industry and young faculty. If this is done properly, it will help solve pay differential problems. This I believe to be a very important point, this disparity of salaries for young faculty. All young faculty in engineering schools are usually given a day a week for consulting purposes. One of the problems is most of the young faculty aren't very interested in industry yet as consultants and therefore, the demand for them is not strong. However, I think the chairmen of all engineering departments should make sure with industry that their young faculty are involved with consulting in industry one day a week. This not only brings back the excitement of real problems to industry and the university, but solves part of the pay problem.

Do everything possible not to overload the young faculty member so that he will have time to be creative. This is a nice thing to say, but if you have an enormous undergraduate body and a few faculty, it is very difficult to meet that.

Then, help resolve the difficult problems of modern facilities. In high technology, facilities are expensive and become obsolete rapidly. Faculty and facility exchange with other universities and with industry may be essential. This is a very complex problem, and no easy solution is known to it.

I think industry should take the time to understand modern problems facing our engineering schools and be sensitive to their problems. They should establish real working relationships to help guide university research and help resolve dilemmas as they develop.

Provide staff, as required, for part-time participation in university teaching and research activities. Make sure this is top staff. Don't just feed off the bottom. Provide specific fellowship support when needed. And then again, help organize consulting arrangements with the young faculty members to involve them in the excitement of modern high-technology programs that are in industry.

Now, the Government. I think one of the main things that we need today is the real facts about what's going on. We have had all sorts of data presented over the last couple of years. I'm not sure that we all agree that we know what the facts are.

For example, the dilemma of manpower shortages, where are they in detail, and so on. I think to provide some top engineering fellowships in important areas is important, and insure that various Government agencies are encouraged to place research programs in our universities that focus on the real world of operation-

al needs. This is most important to defense as the effect of the Mansfield amendment is slowly disappearing.

The involvement of university faculty with defense problems is of crucial importance. I would like to expand on that a little bit. One of the major decisions that was made during World War II was made by Dr. Vannevar Bush. This was that research in support of the war would be done as much as possible within the university environment. He did not want to set up national laboratories unless we absolutely had to.

He wanted to insure that the research took place in the universities where students were and where the faculty would operate in a creative environment. We did create national laboratories in some cases, but by and large, that decision of Dr. Bush had a powerful influence on how the universities operated then and are still operating today.

I think the Government should encourage departments like Defense and NASA to maintain their basic research programs in the universities and not to pull them in-house. The tendency is to say we can do this program better in-house than they can at the university. They should be discouraged from doing that.

Reemphasize the assignment of military personnel to certain graduate schools. The very successful program of many years ago has been largely abandoned. I think this should be reinstated. The educational level of industry keeps going up. The educational level of our top military commanders is going down. This should be reversed at once.

Now, in conclusion, Mr. Chairman, we do indeed have serious problems in engineering manpower. Partial resolution must come through restructuring and refocusing the engineering programs at our universities. The major changes must come in our graduate programs whose focus over the past years has drifted too far in the direction of pure engineering science.

A major factor in solving these problems will be the rapproachment between high technology industry research programs and our university graduate programs. There are new activities starting up to accomplish this. I know you have heard of them. If they are handled with sophistication, our problems should be reduced materially.

Engineering manpower shortages are a real problem today and probably will be so in the next decade. All segments of our society—universities, industry, and government—must cooperate to resolve these dilemmas at once.

Thank you very much.

[The prepared statement of Dr. Perkins follows:]

Statement by
C. D. Perkins
President, National Academy of Engineering
on Engineering Manpower Concerns
to the
Committee on Science & Technology
U.S. House of Representatives
October 7, 1981

Mr. Chairman:

I consider it a privilege to have been invited to appear before you today to present my views on "Engineering Manpower Concerns," a subject that is rapidly achieving national visibility. Although I am sure there is very little on this subject that you have not heard before, I am glad to have this opportunity to summarize these concerns as I see them.

This statement is coordinated with that of my colleague, Dr. Frank Press, President of the National Academy of Sciences, whose testimony you have just heard. Dr. Press's Academy, the NAS, and my Academy, the National Academy of Engineering, are deeply concerned with this problem and are working and have been working on several aspects of it.

Let me start then, by saying that in my opinion there is little question that we are facing shortages in engineering manpower, particularly in specific fields such as electronics, computer science, chemical and petroleum engineering, energy and environmental engineering and bio or genetic engineering. That this is unquestionably so can be verified by the very large salaries being offered by industry trying to fill shortages on a tight schedule. One question comes to mind: "Is this shortage in a cyclical phase which will correct itself in a short time, or are we facing a long term trend

that if uncorrected will have serious impact on our economic wellbeing and the continued viability of our National defense." My feeling is that we are in the midst of a broad expansion of national requirements for engineering and technical manpower, and the shortages will become more serious in the next few years. We, therefore, must not just ignore the problem and hope it will go away. We must take active steps to solve or reduce our problems at once.

Our national shortage of engineering manpower can be reduced in several ways, but the major source of new supply comes from the output of the engineering and science programs of our universities. It is therefore important to examine problems in these educational programs in looking for relief.

The situation today has many dilemmas. First of all, we have had a steady expansion of our undergraduate enrollments over the past five years. Not only are we better off in numbers, but in quality as well. This large expansion in numbers comes from several motivations. Certainly there are exciting new technical fields and exciting career prospects. Secondly, the high pay now being offered by industry has not gone unnoticed by our bright, ambitious young people. An engineering education is also now considered as an excellent background for graduate study in the major professional fields such as business, law and medicine. We have the undergraduates -- now what's the problem?

The problems seem to focus on the graduate education and research programs of our universities. As our undergraduates turn more to industry after receiving their BS degrees, the graduate enrollment is falling off seriously. Graduate student complements are being filled by foreign student applicants who may well return to their home country on graduation. The fall off in Engineering PhDs is having a serious impact on the staffing of our

engineering schools needed to teach our large undergraduate classes. A young person who really wants to have a career in the university finds himself heavily overloaded, working with worn out research facilities, and poorly paid relative to his counterparts who have gone directly into industry.

The dilemma is serious because almost all modern universities make a PhD or SCD an absolute requirement for assignment to a teaching position. One could argue that if all of our top engineering BS students went directly to industry where their continuing education would be handled better with exciting problems and superb facilities, there would be no need for the university graduate programs except for the PhD requirement for faculty. If this were removed and equivalent industrial experience allowed, we could fold up graduate engineering education in the universities altogether.

I certainly do not recommend this, as the university environment is an excellent one for teaching and research, and if our graduate programs have shortcomings today, we ought to fix them. Industry should not have to do its own education and should count heavily on the graduate programs. Many of our most brilliant new inventions and innovations have sprung from the university environment and we should value this work. Some of the reasons it is not working very well today are the result of a gradual separation of university and industrial research objectives since World War II. The universities' research programs, almost fully funded by Government, have drifted further and further to the scientific end of the technical spectrum. The new PhDs supported by these programs become the new young faculty, with less and less knowledge of the real interests of industry. Most of us recognize the problem and are trying to reestablish industry-university research programs to turn this trend around. A great deal of effort is now in progress and most certainly will be expanded in the next few years.

The interconnection between modern high technology industry and graduate engineering at our universities must be accomplished with sophistication. If it is to be successful, a real quid pro quo must be established satisfying the interests of both parties. This can be done and has been done in the past, but we seem to have lost our touch in many cases. This must not be merely an industrial handout, but a significant working relationship of mutual interest.

The solution to our engineering manpower shortage will require us to maintain large enrollments in our engineering undergraduate programs and make them more available to our various shortages. This will require an emphasis on the advantages of an engineering career, and the proper teaching and motivation of the young students. This requires an adequate supply of well motivated and well satisfied teachers who find a career in our universities rewarding and eminently worthwhile. Again, I believe that this can be accomplished best by the integration of industrial interests with those of the university in order that good teaching and good research can be accomplished in the face of various shortages.

As was mentioned by my colleague, Dr. Frank Press, the National Research Council, the operating arm of both the NAS and the NAE has been erecting a major study focusing on the broad problem of engineering education and research. This study will deal with the whole spectrum of concerns mentioned at these hearings. This major study is being undertaken under the auspices of the NRC and has been underway in a Phase I for nearly one year. The results of Phase I which was designed to bring forth a study plan for Phase II has been funded by the NSF under the direction of Jack Sanderson. Phase II will bring in other government agencies who are all deeply concerned with these problems and are agreeing to provide both intellectual and financial support.

Many of these problems are of immediate concern and, as a consequence, progress reports from this study will be provided at regular intervals. Your Committee will, of course, be provided with these as they become available.

Another aspect of the engineering manpower shortage is at the secondary or technician area. These are the young men and women who will become machine tool operators, engine mechanics and so on. These are in short supply and are essential to both industry and the military. A major source for these technicians comes from our rapidly expanding Community Colleges or Trade Schools. Some of the most interesting activities are being undertaken today at these levels. An example is the Community College of the Air Force. This program involves enlisted personnel in first class technical programs using the magnificant facilities available at most operating bases. The supply of first class technician support is crucial to both industry and to the military.

Now, Who Should Do What?

Universities

a. Search out effective working relationships with modern high technology industry, insuring that a real quid pro quo be established.
b. Motivate faculties to take better advantage of industrial staff as adjunct professors.
c. Require, in most cases, real industrial experience for engineering school faculty appointments.
d. Do more to encourage consulting arrangements between industry and young faculty. If this is done properly it will help solve pay differential problems.

e. Do everything possible not to overload the young faculty member so that he will have time to be creative, and

f. Help resolve the difficult problems of modern facilities. In high technology, facilities are expensive and become obsolete rapidly. Faculty and facility exchange with other universities and with industry may be essential.

Industry

a. Take the time to understand modern problems facing our engineering schools and be sensitive to their problems.

b. Establish real working relationship to help guide university research and to help resolve the faculty dilemmas as they develop.

c. Provide staff, as required, for parttime participation in university teaching and research activities. Make sure this is top staff.

d. Provide specific fellowship support when needed.

e. Help organize consulting arrangements with the young faculty members to involve them in the excitement of modern high technology programs in industry.

Government

a. Help develop the facts concerning engineering manpower shortages and the causes.

b. Provide some top engineering fellowships in important areas.

c. Insure that various government agencies are encouraged to place research programs in our universities that focus on the real world of operational needs. This is most important to Defense as the effect of the Mansfield Amendment is slowly disappearing. The involvement of university faculty with Defense problems is of crucial importance.

d. Reemphasize the assignment of military personnel to certain graduate schools. The very successful program of many years ago is largely abandoned. It should be reemphasized.

e. Provide tax and patent incentives to foster the industry/academia relationships.

In conclusion, Mr. Chairman, we do indeed have serious problems in engineering manpower. Partial resolution must come through restructuring and refocusing the engineering programs at our universities. The major changes must come in our graduate programs whose focus over the past years has drifted too far in the direction of pure engineering science . A major factor in solving these problems will be the rapproachment between high technology industry research programs and our university graduate programs. There are new activities starting up to accomplish this -- and if they are handled with sophistication, our problems should be reduced materially.

Engineering manpower shortages are a real problem today and probably will be so in the next decade. All segments of our society, universities, industry and government, must cooperate to resolve these dilemmas at once.

Thank you for giving me the opportunity to present these views to your important Committee.

Mr. FUQUA. Thank you very much, Dr. Perkins.

Dr. Press, you indicated I think in your testimony that we will probably have a balance around 1990. Dr. Perkins, you suggested the shortages will continue to be more serious.

Dr. PERKINS. I said for the next decade, anyway.

Mr. FUQUA. There appears to be a difference of viewpoint.

Dr. PRESS. Let me supplement my comments on this topic. I am skeptical of some of the recent studies because, as I stated in my remarks, I think they have underestimated the needs of our middle level technology industries and of our smaller companies for improving their technical capability to compete with other countries.

I don't think this has adequately been taken into account. But, there are studies which suggest that by the end of the decade, the free market process will bring into balance supply and demand, except for certain fields. By the end of the decade, the same studies point up that in certain areas, in computer sciences and those highly skilled people who can design integrated circuits and program them, information communications, toxicology, biotechnology, et cetera, there will be shortages. But across the board, these studies indicate that by the end of the decade, we should have balance.

But 10 years from now, is a long time. A lot can happen in the competitive standing of this Nation in world markets over the next 10 years. I don't think we should be lulled into a sense that there is

no problem because of a notion that perhaps after the decade these issues will go away.

Mr. FUQUA. But what's the average time to train an engineer? About 5 years?

Dr. PERKINS. At the BS.

Mr. FUQUA. So, you have a 5-year lag time.

Dr. PRESS. That's right.

Mr. FUQUA. Depending on when the demand starts moving, you could very well be delayed in achieving the manpower needs by 5 years.

Dr. PRESS. We can bring students back for master's degrees over a 1-year or 2-year period. We could have midcareer retraining programs. There is some concern that our engineering profession is graying in the sense that the average age of a practicing engineer is increasing. The most creative engineers, as in all fields, are during the years 35 to 40.

Mr. FUQUA. You want to comment on that, Dr. Perkins?

Dr. PERKINS. Well, I agree in principle. I think that as we look forward, say in the area of electronics and computer sciences and we don't see any end to the shortage. But, if you take the whole field as an entity, certainly there is going to be a lot of shifting from one part of the field to another.

I'm an aeronautical engineer, but I don't think there is any shortage of aeronautical engineers today. Whether there will be 10 years from now depends on many factors. But, I do think that we see this broad expansion of national requirements of society for engineering background.

As I pointed out, a lot of bachelor's in engineering are going to the medical schools, the business school, and the law schools. Engineering is becoming a very pervasive field. It supports many things which it never did 10 years ago. My instinct—certainly none of us know for sure—is that this demand and this problem is going to be with us for years. We better get at it.

Mr. FUQUA. The American Association of Electronic Engineers estimate a shortage of 110,000 electronic engineers by 1985. The thing that concerns me, Dr. Press, about the marketplace taking care of it is that by the time we achieve that equilibrium of demand and numbers, what will happen to our economic competitive edge during that period of time where we have lost a lot of computer science industry to other countries, namely Japan?

The statistics show a rather rapid increase over the last number of years in advanced degrees and engineering in Japan, much higher per capita than in the United States. Those are things that concern me.

We had General Marsh testify yesterday, who is the head of the Air Force Systems Command. He testified that he was 10 percent short of engineers today and saw this as a critical matter in the future, just in manning military contracts and the inefficiencies that builds in because you have inexperienced nonengineers or maybe they are inexperienced engineers. These are the things that concern me.

You mentioned in your testimony the alarming slippage of comparative quality regarding scientific and engineering faculties com-

pared with those of some of the other industrial nations. That in itself is rather alarming.

Dr. PRESS. I share those concerns with you, Chairman Fuqua. It was brought home to me Monday night when I visited the president of a corporation in Dallas. The growth limitation on his business today, he told me—it is a major corporation—is the availability of manpower. He has the capital, the know-how, the technology. He conducts business not only in this country but as well in a worldwide market.

I think many companies are beginning to realize that these bottlenecks, the shortages of manpower will restrict our ability to compete and to grow economically as a nation.

Mr. FUQUA. Dr. Perkins, in your view, have the university-industry cooperative programs such as those supported by NSF been useful in trying to address some of the questions you raised in your testimony?

Dr. PERKINS. Well, they used to be. The new ones that are being generated give hope that we will get some of them back on the track. Certainly back before World War II or in that era, industry was heavily involved with graduate programs in universities.

I remember in 1939, I was going to MIT. There was industrial support of the research programs at MIT. Since that time, it has dropped to nearly zero. It is all being supported by NASA, Air Force, Navy, and so on. But, I think the new feeling is that industry has got to get back into it. The thing that concerns me the most is that if they do get back into it, they should do it with real problems, not just handouts.

That would be deadening to the program. But, to give a program to MIT to solve one of their real problems, that's something else. That will solve the faculty pay, and the student excitement as well.

One of our main problems is that the excitement in the graduate programs in universities is being diminished. The excitement has largely moved to industry. That is one of the reasons, besides that of money, that the bachelors are all moving there. That's where the excitement is.

Mr. FUQUA. We hope some of the provisions in the new tax bill will help stimulate that, both actual research and I think as one of you mentioned, instrumentation.

Dr. PERKINS. I can't emphasize enough my feeling on this. In industry or Government, whatever is done should be done with a real quid pro quo, not just handouts. The Government is doing it through basic research programs with our universities. They should be encouraged to continue. Harold Brown when he was Secretary of Defense and John McLucas when he was Secretary of the Air Force sent out memoranda to their staffs saying that he wanted to be sure that they understood that he wanted a major part of basic research programs to go to universities.

Mr. FUQUA. I certainly agree. One of the concerns that we have is that programs such as NSF are being cut back.

Dr. PERKINS. Yes; that's a problem. It is not such a big problem in the engineering side mainly because there is so much of the engineering research supported by the operating agencies. I did some looking around. I found that MIT had $100 million worth of sponsored research in engineering across the board, of which $3

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million or so came from the NSF. Therefore, the NSF is not a large part of the problem.

The main support at MIT is Defense, NASA, Transportation, Energy, and so on. I don't think many people in my own university arena understood that.

Mr. FUQUA. Not all universities are MIT's.

Dr. PERKINS. No. But, I think the percentages may be the same.

Dr. PRESS. I should point out that a good portion of this $100 million goes to Lincoln Laboratory, a laboratory exclusively dedicated to defense research that is off-campus and managed by MIT.

Mr. FUQUA. Mr. Dunn?

Mr. DUNN. Mr. Perkins, I appreciate your testimony, particularly the last set of recommendations you had. I'm from a university community. I'm well aware of a couple of problems you talked about. One, the problem of making sure that a certain percentage of our professors on any university staff have industry background.

I think that applies to the department of engineering as well as any department in a university. Number two, discouraging them from, once they have done the basic research, letting it leave their own house as you pointed out. Coming from a university community, I'm well aware of the resentments and jealousies that build up between the two different factions in the community.

I support your suggestions. I wonder if I couldn't have some more details on how to get beyond that? What are you suggesting? Maybe that we establish some sort of quota system that we would pull back on Federal funding if the university doesn't establish a certain percentage of professors? I don't think you are suggesting that.

But, I would like detail on how to implement the kind of recommendations that you are talking about. I strongly support them.

Dr. PERKINS. Are you referring to the number of faculty that have industrial background, or how we keep the operating—keep the research from being pulled in-house? There are two different questions.

In Defense, it needed a letter from Harold Brown and John McLucas to the agencies to say don't pull this in-house. Leave it at the engineering schools.

Mr. DUNN. I thought you were talking about once an engineering school does research, then not letting it out. That is a problem, too.

Dr. PERKINS. It is a problem, too, but not the one I am referring to. NASA laboratories, for example, in aeronautics, might say well, we will give a contract for research to Purdue or Michigan State to do some research on air foils. The staff will say we can do that much better in-house.

But, on the other hand, they have a responsibility to insure that Michigan State has some real problems. It helps solve many of our problems.

Mr. DUNN. Do you have any idea at the Federal level what we could do in terms of establishing guidelines to make sure that departments have a certain percentage of staff with industry background. Have you any ideas on that?

Dr. PERKINS. It is a matter of a mental state. I spent all of my career at Princeton. Now, it is kind of un-American or un-Princetonian or something to have an adjunct professor. How can you

have anybody that comes from the outside industry to mix successfully in this academic environment?

Two of the most successful faculty at Princeton did have such appointments. They both worked for Bell Labs and they both won Nobel Prizes. But, they were half-time at Princeton and half-time at Bell Labs. It worked fine. But, it is very difficult to do that.

Mr. DUNN. If you have any specifics about how we might implement that, I would appreciate it.

Mr. FUQUA. Thank you, Mr. Dunn. Mr. Brown?

Mr. BROWN. I'm not sure I really have any questions. I would like to offer an observation. Maybe it will solicit some comments.

It seems to me that the major focus of what you are saying is that the immediate problem, engineering manpower shortage, and the quantity of engineering manpower, is really a subset of the problems of how we build quality institutions and quality programs in general. That if we had an ideal type system—and I tend to do a lot of Utopian thinking—I'm one of these compulsive Utopians. If we had an ideal system, it would have the proper mixtures of relationships between industry and government and the educational institutions. We wouldn't criticize our universities for being ivory towers. They would be a part of the community in which they existed. They would be familiar with the excitement that is going on in there.

By the same token, the people working in the industry or in the government would be familiar with the excitement that exists in the university and we would get the best.

So, our fundamental goal really is to have a sound concept of the ideal system that we want to create and work very hard to create it and it will tend to relieve some of these sorts of cyclical problems that we have with fluctuating demand.

Our planning will be better because the various parts of the system will know what the other parts are doing and we will be able to project better 5 or 10 years from now. Individuals will be able to anticipate.

Now, am I correct in this? Because if I am, it leads me to give even more importance to this question of trying to define what the ideal structure is and how we can help to create it rather than focusing on the short-term problems that come up. I have seen these cycles of excess and nonexcess of engineers now for the last 40 years. I am sure you have, also.

All right, that's my question.

Dr. PERKINS. The answer to your question is that's what we must find that solution today in spite of the fact that we have broken these things into pieces and they don't fit well. I don't know whether I was testifying before you, but I made the point that Alan Plunkett, the president of Hughes, one time told us that he didn't want Ph. D.'s out at MIT or Cal Tech anymore before they weren't any use to Hughes when he got them. Therefore, he was going to the schools picking off the top BS candidates before they were ruined by the graduate programs.

Then, they took them into Hughes where the excitement was and where the top innovators were and then they gave them in-house courses and so on to bring up their educational level. That's part of the problem. That should not be.

Mr. BROWN. Well, I won't belabor that. Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Brown.

Mr. Weber?

Mr. WEBER. I do have a couple of questions, although I'm sure we are going to be interrupted by the second bell. I was interested in the course of the debate this year on the National Science Foundation authorization which was somewhat heated. There appears to be virtually unanimity of opinion within the committee that the Reagan administration erred in zeroing out science and engineering education programs.

From your remarks, I would get the feeling that perhaps that was not such a serious error. At least, you indicated that you don't think that those programs are of great importance. I would like to have your clarify your meaning and how you see the value of science and engineering education.

Dr. PRESS. If that conclusion is implicit in my remarks, I should correct them, because I agree emphatically with what you are saying. This is not the time to cut science and engineering education. Quite the contrary. We should support them because of these shortages and because of the problems that are showing up in our schools in the deterioration of the quality of science and math education.

Mr. WEBER. Your remarks were about research, engineering research. Is it safe to say that you feel that those programs are fairly well-funded through other sources and we should focus on things like fellowships that actually get involved in bringing engineers on line.

Dr. PRESS. No; I believe that engineering research has been underfunded in the past. It is an important resource in our engineering schools that has been underutilized. I think that the mission agencies, as Dr. Perkins has suggested, should look to our engineering schools for research and development support. I believe that these schools can provide outstanding support to the Government, in many instances, just as good, if not better than in-house government operations. I also believe that it is the philosophy of this administration to place greater responsibility on the private sector. Perhaps, in this way placing increasing research and development tasks at our universities can aid in solving two problems, support for Government's mission in energy, defense, and so forth, as well as improving the quality of our teaching facilities.

Mr. WEBER. One other program that there was some interest in was the agencies being directed to recruit more women and minorities. I don't have a great familiarity with demand there or lack of demand. Could you comment on that? Is there any growth in the number of women and minorities entering the engineering profession?

Dr. PERKINS. I think the answer is there is some growth, but nowhere near the rate that we would like.

There have been large efforts made by industry and the Government to improve this situation, particularly minorities. The NASA head of engineering was involved in that. They set up a program with at least 30 or 40 entrants in it which tripled the number of

minorities in the program. That program has been working, but not to the level that had been hoped for.

As far as women are concerned, I think the answer is a lot of them are taking bachelor's degrees in engineering, but they are not going into engineering after they finish. They then go to medical schools or other schools. But, it is increasing. But not at a rate that you would like to see.

Mr. WEBER. Thank you, Mr. Chairman.

Mr. FUQUA. Thank you, Mr. Weber.

Dr. Press and Dr. Perkins, we thank both of you for your contributions this morning on a subject we are very concerned about and interested in. Thank you.

This committee will be adjourned.

[Whereupon, at 11:09 a.m., the hearing was adjourned.]

[Additional statements submitted for the record follows:]

APPENDIX

Additional Statements Submitted for the Record

STATEMENT BY DR. GEORGE A. KEYWORTH, II
DIRECTOR, OFFICE OF SCIENCE AND TECHNOLOGY POLICY
EXECUTIVE OFFICE OF THE PRESIDENT
BEFORE THE
COMMITTEE ON SCIENCE AND TECHNOLOGY
U.S. HOUSE OF REPRESENTATIVES

October 7, 1981

Chairman Fuqua, Members of the Committee, I am pleased to submit this statement on an issue that all agree is an important one - engineering manpower.

Few would argue with the premise that our National technological capabilities have provided the basis for an impressive standard of living and a competitive position in the world - from both commercial and national security perspectives. Research and Engineering, and their respective disciplines, form the foundation of that accomplishment. With a growing understanding over the last decade of the implications of this very simple premise have come a number of legitimate concerns about the building blocks of that foundation. The subject of today's hearing - engineering manpower - is one of those building blocks.

The engineering community plays a vital role in technology development through conversion of scientific discoveries into commercial products. A healthy engineering community is essential to the long-term resolution of many of our economic problems. Although there is no simple solution to these problems, it is clear that increased productivity is an important part of the solution. The current consensus, however, tells us that the field of engineering may soon become part of our economic problem - rather than part of the solution - unless issues within the profession are resolved. A variety of statistics

have been cited in documentation of the problem. While they may differ slightly, they all lead in the same direction. The key aspects of the problem include shortages of engineers in several disciplines, shortages of graduate students in engineering and difficulty in retaining and recruiting engineering faculty.

The existing shortage of Ph.D's available for employment in government and industry, as well as in universities and colleges, results mainly from the availability of jobs with industry, where starting salaries for bachelor-level graduates are more attractive and equipment better. The lure of higher salaries and the decreasing quality of life in academia is also causing a migration of university faculty to industry. The implications of these trends are disturbing. With fewer and fewer faculty and engineering students seeking advanced degrees, the supply of Ph.D's is dwindling at the same time that industry's need for doctoral training and engineering enrollment at the undergraduate level is increasing. This situation raises fundamental questions about the capability of the engineering education system to turn out qualified engineers at either the graduate or undergraduate level. The difficulty in solving the faculty shortage problem also is indicative of the long-lead time required by academic institutions to meet new demands, a lead-time which often means that by the time a perceived need is met, the demand has changed.

The engineering manpower problem is not limited to the university community, however; it extends throughout our educational system and encompasses a wide variety of factors related to demographics and our approach to education as a whole. Not only is there a decreasing pool of high school students from which tomorrow's scientists and engineers will come, but those smaller numbers of students

are not receiving broad exposure to science and math in the earliest grades, an exposure necessary to instill interest in pursuing an engineering career. Thus education presents a complicated problem with both short- and long-term implications. Stated in its simplest form, more graduate students and more faculty members in engineering are needed. The simple words, however, do not reflect adequately the extent to which failures in engineering education will affect the Nation's future technological growth. Nor do they capture the symbiosis between industry, academia and the engineering profession that will be required to solve the problem.

It is in this cooperation of the affected communities that the solution must lie. Whenever a serious problem with national implications arises there is a temptation to turn to the Federal government for a solution. In the case of engineering manpower the Federal government does have a role. But that role does not call for direct intervention in what, fundamentally, is a marketplace problem. The problem must and can be worked out by those who supply engineering manpower and those who use it. If there are questions of the quality and future availability of engineering manpower, and certainly there are, it clearly is in the best interests of the industrial "consumer" to take the necessary actions to ensure that his needs are met. The needs of industry for top quality engineers, the requirements of the academic community to meet those needs in a way that promotes continued academic excellence, and the needs of the Nation for technological growth are generally congruent. There may well be perturbations in the involved sectors before a balanced solution is reached. There may even be fundamental changes. As science and technology have produced rapid

changes in our lives over the last decades, the academic and industrial communities must continue to adapt and restructure to meet changing circumstances.

These fundamental facts of the marketplace clearly are being recognized by industry. As stated by Dr. Lewis Branscomb in his testimony before this Committee, IBM has awarded 278 graduate and predoctoral fellowships in mathematics, science and engineering over the last three years. He also stated that IBM plans to make 180 grants to universities between 1980 and 1984 to support new science and engineering initiatives chosen by the universities. In a similar vein, Exxon Education Foundation has announced a $15 million engineering education program which will provide support for engineering doctoral candidates at 66 colleges and universities. The program also will provide funds to 100 university departments of engineering for salaries for professors who might otherwise seek higher paying jobs in industry.

These types of actions alone will not solve the problem but they are a step in the right direction. The many discussions and symposia on the engineering manpower issue have produced a variety of suggestions for additional activities aimed at the many complexities of the problem. A key factor among those suggestions is increased interaction among the academic and industrial sectors and professional engineering societies. We support the thrust of these suggestions that recognize the appropriate responsibilities of the involved sectors.

At the same time, we believe that the Federal government, too, has an appropriate role. We must continue to reaffirm the importance of science and technology to the Nation's economic future and national security. Federal budget reductions in science and technology R&D speak not to the value of those fields, but to current economic conditions and the appropriate role of the Federal government. We must encourage our younger generation to seek out the challenges offered by science and mathematics and encourage them to enter rewarding careers in the engineering field. At the same time, we must encourage curricula which properly prepare them to do so. Finally, we will continue to encourage all of the sectors involved in the engineering problem to work together to seek innovative solutions.

Presentation to the Honorable Members of the House Science
and Technology Committee
by Mr. Verne Weidman
on Engineering Manpower Concerns Hearing 10/6-7/81

The panel of witnesses to be heard on Oct. 6 and 7 does not include any working engineers. I am presenting my views as a working engineer from industry. Let me also point out that I am a member of the Phila. Section, American Society of Mechanical Engineers (ASME) and active on the National Manpower Planning and Utilization Committee of the National Member Interests Committee of ASME, but today speak only for myself.

You will hear from the witnesses that more engineers are needed. This committee is examining an economic question:What will be the supply of and demand for engineering manpower over the next decade. Unfortunately this economic question is tinged by age bias.

My position is that there is no shortage of engineers, just an underutilization of the ones we have. The academic and military sectors of our economy do not pay as well for engineers as industry. They imply industry is paying too much. I say even industry pay scales do not reflect a strong demand, especially for experienced engineers.

Historical patterns in engineering manpower utilization

I am a survivor. A survivor of the reductions in government R&D (primarily military and NASA funding) a decade ago. These cutbacks tripled the unemployment rate for engineers. This was when news stories appeared on engineers taking janitorial jobs to support their families. The trauma of reduced funding raised our consciousness and motivated us to get involved politically.

Although engineering unemployment dropped back from its peak in '71, by '75 it had swollen again to almost equal the record. In my experience I have observed that during slow-downs some displaced engineers take positions not fully utilizing their skills, moving back when things pick up, while others are lost from the pool forever.

National Science Foundation data shows that 'engineer unemployment rate, lagged by one year, has closely paralled shifts in economic activity' (the GNP). (1) 'Engineering fields provide a clear example of repeated oscillation between "shortages" and "surpluses".'(2)

This cyclic nature reflects on student enrollment and engineering employment. According to MIT's cobweb model, 'The current surge in enrollments is bound to lead to an oversupply of graduates despite continuing growth in demand.'(3) Total undergraduate engineering enrollment has continued upward from a low of under 200,000 in '73 to 350,000 in '79.(4)

If we were in truth in demand our pay would have at least kept up with inflation. As it is, our true purchasing power has dropped 13% over the past decade.(5) While hourly workers typically receive cost of living adjustments plus merit increases,

engineers typically receive only merit which averaged 9% in '80.[6] For engineers with over 10 years experience, a phenomenon called salary compression sets in. Average pay begins to level off and after 30 years experience actually declines. Also, stretchout [time between raises][7] combined with lower median raises squeezes the experienced engineer. The pension reform hearings this past decade gave ample testimony to cases of layoff just short of vesting in a plan.

Future trends

The witnesses call for more engineering graduates and to increase alien immigration. This keeps wages low for the experienced working engineer. It's cheaper to bring a low wage earner aboard who has no house to sell and minimum hiring and relocation expense. It costs $30,000 minimum to hire and relocate an experienced engineer but only about $10,000 for a new grad. Simple economics dictate a large, fresh supply, say the witnesses.

During this present economic downturn, the electronics industry has not gone the standard layoff route. Experience from the '74-'75 recession when capital and R&D spending were cut led to lost market share to Japan. Shorter work weeks and long vacations with some layoffs have become the norm.[8]

Our engineering population is aging. Median age moved from 37 to 40 between '60 and '74 but new graduates will slow this.[9] From a 'Harvard Business Review' article on engineer obsolescence: 'For the first time in our or any nation's history, there are large numbers of technically trained people over 40 years of age in our work force; no generation of managers has had to deal with this phenomenon before. Since our technical and economic progress is in large part dependent on the productivity of this ever increasing older group, it is imperative that we learn more about the relationships among the factors of aging, technological obsolescence, and performance.'[10]

Looking at age per se, intellegence doesn't drop during a persons working life.[11] Performance ratings however are closely related to age as are salary increases. These peak in the 30's age bracket. Job assignments also are age dependent, with those over 40 receiving jobs in the lower part of the complexity scale.[12] Much of our human capital is acquired on the job rather than in formal education.[13]

The problem of skills obsolescence when working in a rapidly changing technology over a long working life must be squarely addressed by employers of engineers. Courses alone are not an effective remedy.[14] It is more economic to update the skills of highly trained employees than to try and find that skill on the outside. Control Data Corp., recognizing the investment they have in their professional talent pool, will use their own computer-based education system for training and retraining as part of an expected no-layoff policy.[15]

Sweden has made employee mobility national policy. An autonomous agency anticipates the job opportunities of tomorrow and retrains workers displaced from mature industries.(16) Japanese employers make a lifetime job committment (17), seek active employee participation in operations and share any economic success.

American management prides itself on efficient use of materials and equipment yet it squanders its most valuable resource: human talent. Management style today, operating on short time horizons, directs job assignments to specialists whose narrow focus precipitates obsolescence when technologies or priorities shift. Human capital (a store of specific skills) is not a physical store of capital goods but a human being, talented and able to adapt to changing conditions.

Ironically the managers of engineers are typically degreed engineers. Except for capital committments, the problems of age bias and underutilization lies within the larger engineering community. Engineering management must recognize their engineering workers are a renewable resource whose effective utilization can continue to create the technologies driving this nation's productivity.

Wrap-up

I started my working career as an apprentice plumber. After a year I went to college and earned my engineering degree. I make as much today as an engineer as I would working as a plumber. Yet there is no National Science Foundation monitoring supply and demand of plumbers, truck drivers, or other non-degreed workers making pay comperable to engineers.

Why does the NSF spend $5MM per year on science resources studies?(18) We are a national resource. While Sec. of Labor, James D. Hodgson spoke on the abrupt termination of government R&D funding in '70-'71 and the lack of forethought on its effect on engineering employment. From this experience 'we did realize engineers constituted a tremendous national resource which the nation should not waste.'(19)

Our effective utilization is one of the keys to improving productivity in this country. Because of our low pay our employers have us standing in line at the Xerox machine, collecting and sorting documents, and doing other jobs wasteful of our professional expertise. If we cams dearer we would get the technicians, drafting and clerical support we need so our minds can focus on developing the machines to improve productivity of this great nation. We have the technology to once again move us all towards a better standard of living. Lets release it!

Verne Weidman,P.E., 130 E. Chestnut St., West Chester, PA 19380

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Answers to expected problems posed by witnesses

1. Its difficult to get people to move out west.
Bring jobs to where the engineers are. For example, GE had excess engineers from solar work in Valley Forge, PA plant but needed engineers on nuclear work in Calif. Instead of laying off in PA, they brought the nuclear jobs to their employees.

2. Lack of faculty and facilities.
Allowing enrollments to double without resources was a decision of college administrators. They can control enrollment if they want.

3. Not enough faculty [illegible]
Academic administrators predict a drop in total college and engineering enrollment by '84 so do not want to add to faculty for the short term.

An observation

The committee has invited testimony from the academics, if you will the producers of the product, and from industry/government the users of the product but not from the product: the working engineer.

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